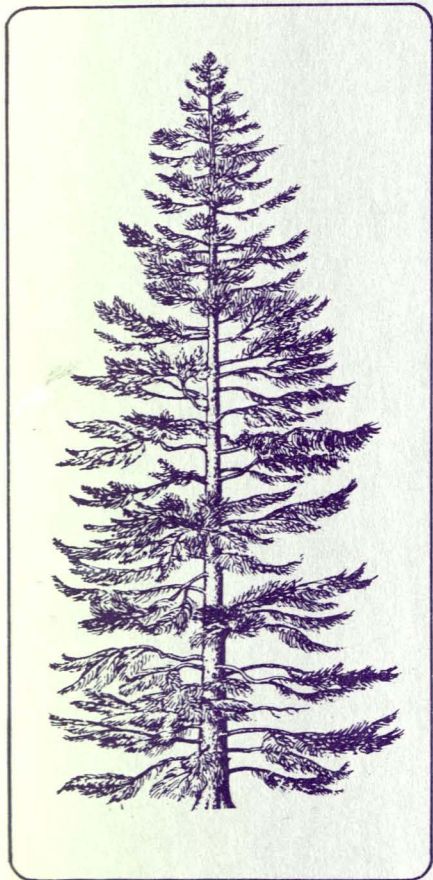


USDA FOREST SERVICE
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JOINT PROCEEDINGS OF THE TENTH LAKE STATES FOREST TREE IMPROVEMENT CONFERENCE



and the
SEVENTH CENTRAL STATES
FOREST TREE IMPROVEMENT
CONFERENCE,
September 22-24, 1971

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

**Mention of trade names does not constitute endorsement by the
USDA Forest Service.**

**North Central Forest Experiment Station
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(Maintained in cooperation with the University of Minnesota)

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Presents 12 papers concerning recent research in forest genetics, physiology, and allied fields. Species discussed include cottonwood, white spruce, jack pine, white pine, aspen, and others. Emphasizes the role of tree improvement in increasing wood-fiber production.

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ACKNOWLEDGMENTS

The Tenth Lake States Forest Tree Improvement Conference and the Seventh Central States Forest Tree Improvement Conference held a joint meeting at Madison, Wisconsin, on September 22-24, 1971. The Department of Forestry, School of Natural Resources, University of Wisconsin, and the USDA Forest Service Forest Products Laboratory were the hosts.

“TREE BREEDING AND THE FUTURE FOR FIBER PRODUCTION IN THE NORTH CENTRAL STATES” was the theme of the meeting. The objective was to explore the future need and the opportunity for cooperative tree improvement efforts in the North Central States. Thanks to excellent planning, the 75 participants enjoyed a successful, rewarding meeting. The Lake States and Central States Tree Improvement Committees wish to thank the University of Wisconsin and the Forest Products Laboratory for hosting the meeting.

Since 1953 the North Central Forest Experiment Station (then Lake States Forest Experiment Station) has published the Proceedings of the Lake States Forest Tree Improvement Conference, and in 1968 the Experiment Station was partly responsible for the Proceedings of the 6th Central States Tree Improvement Conference. The Madison meeting Proceedings are published by the Experiment Station as part of the series of Proceedings. The Tree Improvement Committees wish to thank the USDA Forest Service for this valuable continued support.

Richard Schantz-Hansen

*Chairman, Lake States Forest Tree Improvement
Committee*

David T. Funk

*Chairman, Central States Forest Tree Improvement
Committee*

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THE FUTURE OF FIBER PRODUCTION IN THE NORTH-CENTRAL STATES

W. S. Bromley, *Executive Vice President*
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New York City, New York

It is an honor and a pleasure to make the initial presentation at this Tree Improvement Conference. I plan to cover the "future of fiber production in the north-central States" by confining my remarks to three major issues: (1) the potentials for expansion, (2) factors that may inhibit growth, and (3) changes in policies and procedures required.

POTENTIALS FOR EXPANSION

Before discussing potentials for expansion, I want to be sure we have a common understanding of the main terms of my subject. For example, *fiber production* is referred to by your Executive Secretary Hans Nienstaedt from an economic and silvicultural point of view as "a crop to be harvested in a total system beginning with the harvesting of the tree *seed* and ending as a roll of paper coming off the end of the paper machine." I am sure that the combined papers of this conference may cover such a broad definition — but I will not.

In fact I want to confine the reference of "fiber" to *wood fiber production*. In doing so, I must point out that I am eliminating the possibility of a *vegetable fiber* or even a *chemical fiber* being produced before the end of this century. I mention this to assure you I am very much aware of the hazards of forecasting, and trust you will have your own reservations of long-term predictions.

I am not sure we all have the same concept of what is the North-Central Region. To pin that down, I will note that it is assumed to include the States as grouped in the Forest Resource Report 17, "Timber Trends in the United States." That grouping includes the Lake States of Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin, and the Central States of Illinois, Indiana, Iowa, Kansas, Kentucky, Missouri, Nebraska, and Ohio.

It is important, also, that we have a broad picture of the relative size and importance of the North-Central Region in relation to the total U.S. (including all 50 States) by noting that this region (according to "Timber Trends") has:

1. Nearly 20 percent of the total commercial forest land *area*;
2. barely 10 percent of the total *area* of *sawtimber* stands;
3. just under 10 percent of the *net volume* in growing stock trees, in terms of cubic feet;
4. about 13 percent of the total *growth* of growing stock;
5. only 8 percent of the total cut of growing stock and 10 percent of the total cut of pulpwood; and
6. more than 10 percent of the total growth of sawtimber volume but less than 7 percent of the total annual cut.

Briefly stated, the region has a minor role in the National Forest economy; it has few negative balances between growth and cut, and obviously has room for improvement and great potentials in the years ahead.

Speaking of potentials, let us now get back to the subject of potentials for expansion of fiber production in this region. Keeping in mind the relative position of the region in the national economy, I want to refer to two recent projections of national demand for forest products by two economists highly regarded in their respective fields.

The first projection (table 1) is derived from statements made by Dr. H. R. Josephson, Director of Forest Economics and Marketing Research, USDA Forest Service, in his paper at the annual meeting of Technical Association of the Pulp and Paper Industry (TAPPI) on February 24, 1971. Dr. Josephson gave statistics

Table 1. — Estimated demand for forest products in the U.S. from 1970 to 1990¹
(In million cords)

Year	Pulpwood ^{2/}	Saw logs, veneer logs, etc.	Total forest products
1970	87	100	187
1980	122	137	259
1990	167	165	332

1/ From H. R. Josephson's Paper before TAPPI in New York City on Feb. 24, 1971.

2/ Includes "apparent" consumption in cord equivalents of net imports of pulp, paper and paperboard products.

which indicated that "apparent" pulpwood consumption (i.e., including cord equivalents of net imports of paper, board and wood pulp) would increase from 87 million cords in 1970 to 167 million cords in 1990. The total consumption of all forest products would increase from 187 million to 332 million cords, i.e., an increase of over 70 percent in just 20 years. At this rate the total consumption of forest products would be double current rates by the year 2000.

A more conservative estimate of total demand was presented by Dr. George Cline Smith, President of Mackay-Shields Economics, Inc., at the annual meeting of National Forest Products Association (NFPA) on May 10, 1971. I have converted his estimates from cubic feet to cords by assuming 80 cubic feet to the cord; the results are shown in table 2. Dr. Smith estimates that total demand for all forest products may increase from 177 million cords in 1969 to 281 million in the year 2000. This is an increase of only 60 percent — as compared with a projected increase of 70 percent in 1990 by Josephson (or about 100 percent if projected to the year 2000). Dr. Smith's staff came up with the conclusion that the demand for sawtimber and veneer logs might increase only 10 percent annually over the next 30 years — and that most of the projected 60 percent increase by the year 2000 would be in expansion of demand for pulpwood, i.e., wood fiber.

Table 2. — Estimated demand for forest products in U.S. from 1969 to 2000¹
(In million cords)

Year	Softwoods	Hardwoods	Total forest products
1969	121	56	177
2000	183	98	281

1/ From G. C. Smith's paper before NFPA in Wash., D. C. on May 10, 1971.

In light of these two competent but diverse estimates, it seems reasonable to predict that fiber production in this region should double in the next 20 to 30 years. Since consumption in this region in 1970 according to American Pulpwood Association figures (excluding Kansas, Dakota, and Nebraska) was 5,226,000 cords, we are talking in terms of 10,000,000 cords plus by the period 1990 to 2000. This seems even more reasonable when you look back 20 years and note that pulpwood consumption in this region increased just a little over 100 percent. If I had given you a prediction based on that fact alone in the first place, it would have saved us both a lot of time and words. In any case, an annual expansion of 2 to 3 percent for this region may well be the trend.

FACTORS THAT INHIBIT GROWTH

Any estimate of the future use of commercial forest land for growing forest products, and of producing and selling such products, is fraught with more unfavorable or unknown factors than at any time in the past. I will mention only those which are most timely and significant; for example:

1. Competition for forest land is increasing. Non-timber uses and demands are increasing. Complete withdrawals from forest production are caused by parks, highways, reservoirs, and agriculture; these total as much as 10 percent of the timber cut annually for commercial use, according to Dr. Josephson.

2. The public awareness and complaints on pollution of streams, rivers, and lakes are actually closing mills, or forcing them into expensive capital investments that may make fiber production unprofitable for some mill operations.

3. Consumer programs geared to reduce or eliminate some forms of pulp and paper packaging are already getting legislative attention and support. This could seriously reduce existing production and eliminate expansion of some pulp manufacturing plants.

4. Insistence on using high or uneconomic percentages of recycled papers may seriously disrupt current and future fiber production.

5. The demand for more esthetic consideration in timber harvesting, especially in clearcutting, is causing consternation (to say the least) among practicing foresters on both public and private lands.

Surely, the above represents a serious enough list without going into the rising costs of labor, stumpage, and ad valorem taxes, or the threat of governmental interference and control of forestry practices on public and private lands, if bills such as the one proposed by Senator Metcalfe receive any favorable action by Congress. In short, even the most conservative estimates of demand may not be fulfilled unless reasonable and economic solutions are soon developed to solve these problems by our legislators.

CHANGES REQUIRED

In spite of the threatening array of problems I have listed for your review, I am enough of an optimist to believe they will be solved to the extent that an expansion of fiber production at a 2 to 3 percent rate in this region can be expected, *providing* we take more intensive action in changing our practices and policies. When I say "our" I am referring to foresters, managers of the private and public organizations, and legislators. Some of the concerns we must include in our consideration are:

1. Our primary and immediate concern probably should be in getting more adequate information to the public and to the consumers of forest products as to what we are doing to maintain and improve our forest resources and our general environment. We must explain what may be involved in meeting the myriad of demands for improved use of water, different forms of packaging, changes in methods of harvesting forests, etc.

2. In order to meet newly established standards, our pulpmills are already embarked on massive programs to discover ways and means of using less water or of returning it in the same condition that it was prior to use.

3. Most pulp mills are using as much sawmill and other solid wood product mill residues and so-called logging wastes as is economically feasible. Studies and pilot operations on utilizing the whole tree are well underway. The recent demonstrations of the Metro Chiparvestor in this field are, I'm sure, known to you since the main plant of the manufacturer, Morbark Industries, Inc., is located in Winn, Michigan. These potentials, which can double the yield of wood harvested per cord of this region, must be explored to the fullest.

4. If there are any foresters left who feel that commercial forest land must be devoted only to the production of wood fiber or other forest products, I feel they

better seek early retirement at the first opportunity. The pressures for using commercial forest land for recreation and other nontimber growing activities require intensive application of multiple use principles.

5. Improving forestry practices and increasing production of forest products on the lands of farmers and miscellaneous private woodland owners is a major need in both this and all other forest regions of the country. This need is not likely to be met by industry, and unless it is stimulated by direct subsidies or incentive tax policies of our government, it will be a primary cause of failure in our forest policies. These ownerships (farmers and miscellaneous) comprise almost two-thirds of the commercial forest land in this region. Their improved management must be given the highest priority of attention and action.

6. Even if all the above changes were acted upon promptly and in full measure, I doubt if they would be adequate to meet the needs of our economy by the year 2000, even if we succeed in reaching zero population growth in this country by that time. Unless we have increased consideration and action on needed forest research programs, we are likely to be faced with failure in meeting our need for forest products at that time.

Our own industry sincerely believes and supports forest research. For the past 4 years, six of our own members have supported a harvesting research project that has an annual budget in excess of \$350,000. Next year the sponsorship of this program will be expanded to 12 to 15 companies. These are primarily companies with southern mill operations. I need not tell this audience that southern pulpmill operators are currently supporting some of the most intensive research in forest tree improvement, and applying the results on a region-wide basis over hundreds of thousands of acres annually. Similar efforts and programs in this region on a proportionate scale of interest and action are presently not in evidence. I am not being critical — but I do believe that all concerned with these problems in the North-Central Region should take more progressive steps to stimulate the needed research in improving the quality of seed and growing stock that will make up the future forests in this region.

I am sure the papers that follow will outline very specifically why this is needed, and how these programs would be conducted. Pay close attention and consider their recommendations with care. The future forest and the future citizens of this region will profit accordingly as you listen and act on their recommendations.

GENETICALLY IMPROVED CONIFERS FOR THE LAKE STATES

Jonathan W. Wright, *Professor of Forestry*
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East Lansing, Michigan

The Lake States provenance test of jack pine was started by Paul Rudolf of the USDA Forest Service in 1951. That marked the beginning of two decades of serious tree improvement research in the region. In this paper I shall recount some of the progress that has been made. But it is also necessary to consider the extent to which genetic improvements have been put to practical use. We cannot expect continued research support without providing evidence that better trees are being planted because of our efforts.

GREAT GAINS IN CHRISTMAS TREE SPECIES

The past two decades have seen the rise of a sizeable Christmas tree industry based upon plantation culture. Planted Scotch pine, white spruce, Douglas-fir and a few other species have all but replaced the wildlings of 20 years ago. I do not have figures for all States, but in Michigan there are about 10,000 Christmas tree growers and the annual harvest is more than 5 million trees; the good trees wholesale at prices of \$1.75 per tree and up. Tree improvement research has had a great impact on the Christmas tree industry. It is probable that between 75 and 95 percent of the nursery stock available in 1971 bears some imprint of tree breeders' activities.

Scotch pine is the most popular Christmas tree in this region. It is an extremely variable species geographically, with 4 to 1 differences in growth rate, variation from lemon-yellow to dark-green winter foliage, 2 to 1 differences in needle length, and corresponding variation in other traits. Prior to 1960, many growers planted varieties that turned yellow in the autumn; such varieties had to be sprayed with green paint at a

cost of \$0.25 per tree if they were to be sold. Also, varieties from Belgium, northern France, and the western part of West Germany were commonly planted. Those varieties have moderately acceptable color and grow so rapidly as to require that every branch be sheared every year. The introduction of dark-green, slower growing varieties from southern Europe has resulted in increased tree quality and lower production cost. The color improvement alone is worth from 0.5 to 1 million dollars per year to the growers. Also, evidence this past year indicates that southern varieties are much the most resistant to pine root-collar weevil.

White spruce is another high-volume Christmas tree. Native seed has been used most commonly. Trees grown from seed collected in eastern Ontario grow 10 to 15 percent faster, which means a reduction of 1 to 2 years in rotation length.

Douglas-fir, the high-volume Christmas tree of the Pacific Northwest, is also much in demand in the Lake States, commanding wholesale prices of \$4.75 per tree. This, like Scotch pine, is an extremely variable species geographically. Much of the stock planted prior to 1965 in Michigan was grown from seed collected in central Montana, the home of slowest growing of all races. Rotation ages of 15 to 20 years were commonly assumed to be necessary and there was little profit even at \$4.75 per tree. Now there are 10-year provenance-test data showing that Douglas-fir from Arizona-New Mexico and northern Idaho can be marketed in 5 to 8 years.

Genetics research has also resulted in improvements in four other species — balsam fir, Fraser fir, white fir and southwestern white pine. Trees of those species promise to be of premium quality and could be grown on 5- to 8-year rotations.

REASONS FOR PROGRESS IN CHRISTMAS TREES

It so happens that most species being used as Christmas trees are extremely variable geographically. Provenance tests of a simple kind could show the presence of dramatic differences in growth rate and various other traits. It also happens that many growers in the past inadvertently chose the worst possible seed sources. Thus, it has been possible to obtain very dramatic improvements with a minimum of research effort.

Two other obvious factors should be mentioned. Christmas trees are short-rotation species amenable to quick improvement and tree breeders have paid some attention to Christmas tree problems. However, I do not think that either of these factors should be over-emphasized. The region's tree breeders have probably spent three times as much effort on timber and pulpwood problems as on Christmas tree problems.

Very important is the willingness of the Christmas tree industry to accept new developments. Christmas tree growers associations — both State and national — have annual meetings at which they solicit information on the latest developments in many areas — marketing, weed control, pest control, and new varieties. Also, these associations publish journals. All these factors have contributed to the fact that improvements have been put to practical use. The improvements have been dramatic, and Christmas tree growers have been interested in them. And, there are ways by which the information is effectively channelled to the Christmas tree growers.

Even so, success has not been automatic. It has been necessary for the researcher himself to do extension and development work. The Douglas-fir provenance test was started in 1962. A press release in 1965 elicited inquiries about recommended seed sources. No seed dealers or nurserymen handled the sources we were recommending. In 1968 we contacted foresters in Arizona and New Mexico, asking whether there was a cone crop and whether there were collectors. The replies were turned over to seed dealers. More press releases and technical articles appeared in 1970 and elicited more letters from growers and nurserymen. By that time we could recommend several seed dealers and one nurseryman as sources of Arizona-New Mexico stock. Hopefully by 1973 adequate supplies of the varieties now being recommended will be available in nurseries. Efforts such as this are necessary to make tree breeding results of practical value.

IMPROVEMENTS IN CONIFERS FOR ORNAMENTAL PURPOSES

The ornamental use of trees is receiving increasing attention. In the southern, nonforested half of the Lake States, trees possess more economic value as parts of the environment than as producers of raw material for industry. Even in the forested parts of the region, forest policy is often dictated as much by the recreation industry as by wood-using industries, and the public may consider esthetic aspects more important than wood-producing aspects. Thus, the ornamental values of trees cannot be overlooked.

Most improvement in this area has come through the use of species from other parts of the world. Of the 10 conifers most commonly planted for ornamental purposes in the Lake States, six were introduced from Europe, western United States, and Asia. Many other species could be added to this list — Japanese larch, Serbian spruce, and metasequoia, to name three. Most of the region's tree breeders work at least a little with exotics and are acquainted with little-known species that would be useful esthetically.

With the possible exception of jack pine, all the important Christmas tree, pulpwood, and sawtimber species in the Lake States are also useful ornamentals. Virtually all the tree improvement research being conducted in this region therefore relates to ornamental use. Consider for example, the finding that one variety of white fir grows twice as fast as another. That finding is equally important no matter what the reason for planting. Or, consider an improvement in the growth rate of eastern white pine. Growth rate is important whether the white pine is planted in a park or in a forest.

Thus, research directed toward the improvement of Christmas and forest trees has developed as a byproduct a number of findings important in the use of trees for esthetic purposes. Many more such results can be expected. However, the formal tree improvement programs have had almost no impact on esthetic forestry.

Esthetic and commercial forestry are very different in spite of the fact that both may deal with the same types of problems in the same species of tree. The region's tree breeders were trained in commercial forestry and are relatively unacquainted with the problems of esthetics. This is one of the reasons why our work has had little impact on the planting of trees for ornament. We have overlooked the esthetic value of a new

variety and have not known the channels by which to communicate with landscapers.

The introduction of a new ornamental into the trade is not an easy task. Norway spruce was introduced into the United States in the 1600's but only in 1876 did it become commonly distributed in the State of Pennsylvania. Japanese larch was introduced into the United States in 1861 and has become common in New York State during the past 30 years, but is not present in Michigan outside a series of 12-year-old experimental plantations. In Michigan it has obvious merit as an ornamental (also as a timber tree), but more than 110 years might have elapsed without its being used.

I wonder whether we must wait 110 years to introduce a new hybrid pine into the towns and roadsides of southern Michigan. This is a hybrid between Austrian and Japanese red pine. It can be mass produced cheaply, may be resistant to salt spray, and grows faster than any other hard pine in the State. It should be field planted as a 2-0 seedling, and that feature is a disadvantage. Nurserymen servicing the ornamental trade are accustomed to selling larger trees at a high per-tree price. To push this hybrid, we must show nurserymen and landscapers how to make money from 2-0 trees as well as show the merits of the tree.

Any newly developed tree must be marketed through commercial nurserymen. It is they who interpret the public's needs and satisfy those needs. They are private businessmen with profits to consider. For that reason they tend to emphasize clonal lines that can be patented and thus sold exclusively by a few people. Also, they emphasize those varieties which are in demand. They reflect the needs of the suburban homeowner rather accurately, but not the needs of the highway landscaper, the inner-city dweller or the manager of a large rural park.

In recent years large chain stores have become major outlets for nursery stock. Inevitably there has been a tendency to stock only one clone or variety of a single type of tree, a variety believed to be equally successful in Maine and Oregon. This practice is a hindrance to the introduction of a new variety believed to have merit in specific situations.

Formal tree improvement programs in the region have produced many results of value to esthetic forestry, and results of a type not to be expected from amateur breeders. The channels by which those results can be put into practice have not been developed. Real efforts should be made to develop these channels.

THE PRESENT STATUS OF IMPROVED TIMBER-TREE VARIETIES

Improvement of trees for timber production has been the major thrust of the region's tree breeders. Accomplishments, while not as spectacular as for the Christmas tree industry, have been considerable. In white spruce, increases in rate of height growth of 10 to 15 percent have been obtained by using seed collected from eastern Ontario in place of native seed. The increases would be much greater if translated into terms of volume growth. The growth differential was approximately the same whether the test was conducted in North Dakota, Wisconsin, or southern Michigan.

Norway spruce grows considerably faster than white spruce at many places in the southern and central parts of the Lake States. Also, it grows well in Michigan's Upper Peninsula and some other northern areas. On many sites, spruce rotations could be reduced 25 to 50 percent if this species were substituted for white spruce. Norway spruce is subject to attack by white-pine weevil and suffers from old age when it reaches a diameter of 18 inches. Even with those difficulties, Norway spruce grows straight and fast and to greater size than do our native species.

Eastern white pine from the southern Appalachians planted 12 years ago in southern Michigan is now 25 feet tall, surpassing native trees by 10 to 15 percent. Eastern white pine trees from southern Ontario are nearly as tall as those from Tennessee, although not as large in diameter. In tests conducted in Michigan's Upper Peninsula, white pines grown from seed collected in the Lower Peninsula grew 8 percent taller than Upper Peninsula trees. In experiments conducted in northern Wisconsin and northern Minnesota, trees from central Wisconsin grew most rapidly.

It is apparent that no one race of eastern white pine is best for all portions of the Lake States. But it is also apparent that there is a better type of white pine for almost every acre in the region. Increases of 10 to 20 or even 30 percent in rate of volume growth can be expected by a judicious choice of seed sources adapted to particular sites.

Comparable gains have not been obtained in jack pine, where the fastest growing trees are from central Wisconsin and central Michigan. Jack pine growers in those areas should use local seed. There is evidence that moving central Wisconsin-central Michigan seed

northward into northern Wisconsin and parts of northern Michigan (but not into northern Minnesota) can result in a 5 to 10 percent gain in growth rate without encountering winter damage.

Plus-tree selection followed by grafting is the tree breeding method most commonly used in northern Europe and southeastern United States. Its possible usefulness in the Lake States has been tested by means of progeny tests. These are now well underway in five coniferous and one hardwood species. Except in white spruce, the results are negative — plus trees as selected in the fields have not produced superior offspring.

However, another breeding method known as family selection has been tried with some success. The goal of this method, as of plus-tree selection, is to make use of the genetic variability believed to be present in any natural forest for the production of a new variety superior to the wildlings now on the land. A red pine progeny test-seed orchard developed along these lines indicates a 2 to 3 percent gain in rate of height growth, with limited quantities of seed to be available in 1975. Although nursery measurements of a similar jack pine project indicated gains, measurements made 4 years after field planting leave the issue in doubt.

It is still too early to talk of the amount of improvement in tamarack, northern white-cedar, and balsam fir. There are sizable projects underway with these species but the experiments are young yet.

Japanese larch, unlike its relative the tamarack, is a moist upland species. It is a remarkably fast-growing species. Trees planted 12 years ago in northern Minnesota, northern Michigan, southern Michigan, and Nebraska are 1½ to 2 times as tall as neighboring pines and spruces planted at the same time. This rapid growth has made it an important timber species in New York and northern Europe.

Most of these improvements are not being put to practical use, partly due to a lack of a sustained drive on the part of researchers. The results have been publicized more in scientific journals than in newspaper releases and popularized articles that would be read by tree planters. Also, a certain amount of developmental work is necessary before some of the results can be put into practice. In this regard, I think we could borrow from the experience of the user-oriented North Carolina State-Industry program, where use of research data has received as high a priority as the scientific aspects.

Both researchers and tree planters have been loath to accept the results from 10- to 15-year-old experiments as final. We have tended to be overcautious. Undoubtedly some new varieties that show great promise at age 10 will not look so good at age 50. But this will not happen to all new varieties. In deciding to plant something that has been only partially tested, we run a certain risk. But in deciding not to plant anything new, we face the certainty of not improving our forests in the next half century.

The breeding and introduction of a new crop plant variety are only partly under the control of a plant breeder. He makes the original selections, crosses them, develops the new variety, and tests it in experimental plantings. Then he releases it to the public for commercial use, and that is when the real testing starts. Many such new varieties fall by the wayside over the years but a few succeed and raise the general level of agricultural productivity. I think we should follow this agricultural practice and make sure that our new tree varieties receive extensive testing under actual field conditions.

One way to accomplish this with minimum risk is to plant each new variety in gradually increasing amounts in small plantations or even in mixed plantations. One scheme suggested for eastern white pine in southern Michigan is to raise 100,000 Tennessee white pines, give them to nurseries, and ask the nurseries to provide each white pine buyer with 25 percent Tennessee stock and 75 percent Michigan stock. A one-row to three-row mixture would permit testing of the Tennessee trees on a broad scale with little risk.

There has been an unfortunate tendency to consider genetic tree improvement as an alternative to silvicultural management. Instead, we should consider genetic improvement and silvicultural management as complementary procedures. The new varieties will give the greatest amount of improvement if planted on good sites, given good weed control, and given proper management.

IMPROVED TIMBER VARIETIES OF THE YEAR 2,000

I have dwelled on the problem of putting research results to use because we will not have continued support for tree breeding research unless there is evidence that the results have been useful. Also, the tree planting public must become accustomed to the use of new varieties.

The past 30 years saw a tremendous amount of forest planting in the Lake States. Most of the public lands badly in need of cover are now forested. These plantations are providing a source of raw material for industry. Public response to this policy of maximum wood production from every acre has been varied and as of 1971 the wisdom of continued large-scale planting is being questioned from many sides. The wisdom of planting only for timber production is also being questioned. Thus there is no clear mandate for a tree breeder to concentrate on a single species such as white spruce or red pine that would be excellent for industrial use. Nor is there a clear mandate to concentrate on volume production or any other single trait such as wood quality. The needs both as to species and uses will continue to be varied, so I see a continuation of the present practice of working on a wide variety of species and problems.

Nevertheless, increases in growth rate will continue to loom large. Growth rate is an easy thing to measure, progress in increasing growth rate has been shown, and the demonstration of rapid growth is an easy way to obtain research support. As an example of the possibilities, I will cite red pine. The Michigan red pine progeny test-seed orchard program was started in 1961 and by 1975 should yield improved seed. There is promise of a 2 to 3 percent gain in rate of height growth. Plans are already made to start a second-generation progeny test-seed orchard program in 1975. This will use control-pollinated seed and should produce about twice as much gain as the first generation. If the heritability estimates are correct, we may obtain a total gain of 10 to 15 percent in rate of height growth by the third generation, about the year 2005.

Similar projects are planned or underway for other important species — white spruce, white pine, jack pine, and Scotch pine. Such projects are relatively inexpensive, requiring strong effort at intervals of 10 to 15 years and little effort between times. Present data indicate that the gains would not be changed very much by intensifying the effort and concentrating on a single species.

Increased disease resistance is needed in several species. Preliminary results are promising but indicate that we may have to wait some time for truly adequate varieties. I will cite an example from Scotch pine. The Belgian variety is the fastest growing and among the most susceptible to the European pine sawfly and the pine root-collar weevil. The Ural Mountain variety is resistant to the sawfly but not to the root-collar weevil and grows 25 percent slower than the Belgian variety. The Yugoslavian variety is resistant to the root-collar weevil but not to the sawfly and grows 15 percent slower than Belgian trees. It seems likely that we can obtain a good timber variety combining rapid growth, sawfly resistance, and resistance to the root-collar weevil by crossing the three varieties and selecting among the offspring for about five generations.

White-pine weevil is another important insect. Preliminary results from two different types of experiments indicate that there is little hope of obtaining a resistant variety by selection and crossing of eastern white pines in less than 20 or 30 generations. But, western white pine carries a satisfactory amount of resistance and can be crossed easily with eastern white pine. A three- or four-generation hybridization project could give us a resistant variety well adapted to the Lake States.

To tackle the production of these two resistant varieties of trees would be a new undertaking in tree breeding. It would require the preparation of 50-year work plans calling for a series of crosses to be made and test plantations to be established at intervals of 10 to 15 years, faith that the end products would justify the effort, and a single-minded concentration on getting the work done.

Becoming sidetracked is one of the greatest dangers in a long-term project such as I've outlined for Scotch pine and white pine. The approach is old-fashioned, similar to that followed by crop plant breeders for the last 50 years. There are possibilities of shortcuts — of finding a method of rooting unlimited numbers of cuttings of one good early-generation hybrid, of finding the internal cause of resistance, or of hastening flowering so that generation length can be reduced to 50 years.

GENETIC IMPROVEMENT OF HARDWOOD FIBER PRODUCTION IN THE NORTH-CENTRAL REGION: POTENTIALS AND BREEDING ALTERNATIVES

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In the Lake States, aspens are now growing towards senility faster than they are being harvested (Groff 1966). In the Central States, wood processing residues have recently supplied about one-half of the area's hardwood fiber requirement (Blyth 1970), thus allowing hardwood growing stock to continue its recuperation. In fact, the national hardwood fiber supply situation is improving (Hair and Spada 1970). However, a growth deficit is expected by the year 2000, given current management levels and "expected" demands. Josephson (1971) foresees about another decade of adequate fiber supply. Moreover, some of our economists tell us poor biologists that we've got to produce more and more fiber on less and less land. Somewhere between the unharvested senility of aspen and an unrealistic commitment to unrelenting growth, we must settle on a varied, productive forest to supply a stable, fiber-using industry.

Einspahr and Benson (1970) see three aspects to this forest: (1) certain lands for recreation and amenity with timber as a byproduct, (2) some areas for conventional timber management, and (3) good sites near mills for intensive short-rotation fiber production. Genetic improvement of fiber production has a role in all three of these settings. Despite the obvious intellectual and short-range economic attractions of research on intensive hardwood fiber production systems, geneticists, physiologists, and silviculturists must address themselves to the problems of all three levels of practice. Genetic improvement of hardwood fiber production must be considered within the framework of forest management's several regional goals, not as an isolated objective.

We can assume from previous analysis by Dawson and Pitcher (1970) that genetic improvement of hardwood fiber species in the North Central Region is a high priority research and development goal. They conclude that effort should be concentrated on aspen and cottonwood for which there are respectively about 8 and 4 million acres of highly productive sites in the region. Most of my discussion will thus center on probable first generation genetic gains in these species, especially aspen, which have not been subjects of recent review. However, data will also be noted for other northern species such as birch, maple, and oak, for which highly justifiable breeding programs are aimed mainly at improvement of lumber and veneer material; improvement of these species' growth capacity can ultimately add to our fiber supply. Finally, I will briefly review recent data for some southern hardwoods, because they suggest first generation gains that may be expected in north-central species. We will consider growth, wood properties, and pest resistance.

COTTONWOOD

Cottonwood breeding programs are aimed mostly at providing genetically improved material for intensive cultural systems. While these systems may produce lumber and veneer as well as pulpwood, they do so in fairly short rotations (20 to 30 years on excellent sites), at least in the lower Mississippi Valley. Conventional forestry techniques are presently used in pulpwood rotations, but cottonwood may be suitable for "silage" systems. Breeding programs should therefore produce material for both conventional intensive forest management and new methods of fiber production.

Mohn will discuss cottonwood breeding methods in a later paper at this meeting, and Schreiner (1971) has outlined a detailed cottonwood breeding system. My remarks will deal only with expected gains. Most of the data are for populations in the South and are not patently applicable to North-Central Region populations, but they represent a fair estimate of what may be expected farther north.

First, racial variation may be the source of considerable gain in the North-Central Region. Mohn and Pauley (1969) noted that while much material from 32° to 38° latitude was winter killed at a 44° planting site, surviving low-latitude plants exhibited much better second-year growth than local stock (6.0 feet vs. 4.4 feet). Further screening of 32° to 38° sources at higher latitudes should provide some valuable breeding populations for northern areas. A large provenance test now under way in Illinois may produce some of this material.

Most of the southern breeding effort has been concentrated at the USDA Forest Service's Southern Hardwoods Laboratory. The early work of Wilcox and Farmer (for review see Farmer and Mohn 1970) consisted mostly of field selection of good phenotypes followed by short-term (1 to 2 years) screening tests of clones and open-pollinated families grown under intensive culture. Genetic gains computed from test data were expressed as percentages of control populations, the means of which were equal to or slightly above a natural population. Expected genetic gains in height and diameter from selecting the top 10 percent of clonal populations were around 5 to 10 percent. Because of correlation between height and diameter, expected volume gains were 10 to 20 percent. Gains for specific gravity were estimated at 7 percent and for fiber length about 4 to 5 percent. Other characteristics related to growth, such as phenology and *Melampsora* rust resistance, were found to be more highly heritable in these and other (Jokela 1966) tests. Mohn and Randall (1972) have reexamined one of the Wilcox and Farmer (1967) tests at 6 years, and report slightly higher heritabilities than noted for first- and second-year growth, thus suggesting that early gain estimates for growth were probably conservative.

Forty clonal selections made from these screening studies were planted along with a control population of 40 clones in a larger test, and some 4- and 5-year growth data have been published by Mohn and Randall (1969), Randall and Mohn (1969), and Mohn *et al.* (1970). At 4 years, mean volume per tree for the 40

selections was 27 percent greater than for controls, indicating that preliminary selection in screening tests was effective. After the fifth growing season, when a second thinning (to 109 trees per acre) was made, 14 clones were selected from the study for further testing and pilot-scale commercial use. On a good cottonwood site, the mean volume of these 14 clones was 6.5 cubic feet per tree, compared with 3.7 cubic feet per tree for the control population. Three of the clones had mean volumes in excess of 100 percent over controls. The gain represented by these selected clones is realized gain on the test site, not predicted response computed from genetic parameters. Intensive clonal screening and testing should soon result in a number of clones with this sort of growth capability, because the initial breeding population represents only a minute portion of available material.

Exactly how much gain in growth was made in each of the various stages of selection noted above is difficult to determine from available data. Analysis by Mohn and Randall (1969) indicated some gain was made in field selection of phenotypically superior parent trees and at the other stages thereafter. In a 2-year, open-pollinated progeny evaluation using the same selected parents and a 52-family control population, Farmer (1970) observed identical means for juvenile growth of controls and selected families, and concluded that field selection had been ineffective. In this latter test, predicted response (genetic gain) to combined selection of the top 5 percent of the test population was 7 percent for height, 16 percent for diameter, 10 percent for specific gravity, and 5 percent for fiber length.

The Texas Forest Service breeding program includes clonal tests of local selection and material from throughout the eastern U.S. To date, local clones have proved superior in eastern Texas, and after preliminary testing nine were recently compared with nursery-run material in a 4-year-old irrigated test.¹ The best clone, with an average tree volume of 4.0 cubic feet, is producing nearly twice the volume of controls and 45 percent more dry weight. Cottonwood twig borer (*Gypsonoma hainbachiana* Kearf.) damage, which is serious in Texas tests, has not varied appreciably among rapid growing local clones, but was found to be low in a hybrid poplar clone (Woessner and Payne 1971).

¹ Woessner, R. A. Growth, volume, and dry weight differences among 4-year-old *Populus* clones grown under irrigation. Pap. presented at First North American For. Biol. Workshop. 1970.

It thus appears that early estimates of genetic gain in southern cottonwood populations may be conservative and actual juvenile volume gains of up to 100 percent may be realized in first generation selection if enough clones are screened. Numerous tests and pilot plantings are now in progress throughout the Mississippi Valley, and the resulting data should shortly give a reliable estimate of realized gains on a per-acre as well as a per-tree basis. Data from these tests should substantially augment our scanty information on wood properties and pest resistance. Concurrent studies of growth relationships (Larson and Gordon 1969) may provide keys to effective screening for superiority in fiber production.

ASPENS

Genetic information on the aspens can be applied effectively at all three levels of silviculture noted above. The considerable amenity value of an aspen clone is not reduced if it is uncommonly healthy and rapid growing. A recreationally oriented silviculture aimed at a continuous supply of esthetically pleasing aspen will certainly produce fiber. The deer-aspen system of producing game and fiber pioneered by Westell (Graham *et al.* 1963) presents good opportunities for using genetically superior clones. Aspen's clonal habit and regeneration by root suckering enhance the potential long-range benefits of using genetically superior clones on lands managed with traditional techniques. Einspahr and Benson (1968) have already cited the important benefits of short-rotation aspen silviculture.

Early studies of phenotypic variation in growth and wood properties of Wisconsin quaking aspen were reported by Buijtenen *et al.* (1959), who took advantage of aspen's natural clonal habit to obtain rough estimates of broad-sense heritability. Expected gains from selecting the best 5 percent of the population were: height, 10 percent; diameter, 6 percent; specific gravity, 2 percent; and fiber length, 4 percent. Barnes (1969) used the same procedure to estimate broad-sense heritability for height and diameter of *P. tremuloides* and *P. grandidentata* in Michigan. His estimate for trembling aspen diameter was similar to that of Buijtenen *et al.* (1959), but his heritability for height was lower. Heritabilities for height and diameter ($h^2 = 0.34$) of *P. grandidentata* were higher than for trembling aspen. All of these estimates of heritability and gain are probably biased upward, since in studies of unreplicated clones, environment and genetic effects are confounded.

Broad variation in growth of naturally occurring clones of both aspens has also been reported by Einspahr

and Benson (1967), Koenig (1960), and Romeril (1961). Einspahr and Benson used growth data for trembling aspen in Wisconsin to establish base lines for judging potential field selections. In Koenig's study of bigtooth aspen in Michigan, 28 clones were selected for their phenotypic superiority in growth, and were paired with randomly selected adjacent clones. Selected clones had trees that averaged 12 percent taller, were 19 percent greater in diameter, and contained 53 percent more volume than random clones. Six selected clones on the best site sampled had 166 percent more volume than random clones. Romeril extended this sort of selection study to a wider area in Michigan and designated 16 phenotypically superior clones that contained trees 15 percent greater in diameter, 13 percent taller, and with 51 percent more volume. Zahner and Crawford (1965) have shown the importance of considering clonal variation in aspen site evaluation; their data on phenotypic differences are in agreement with those above. Because of aspen's natural replication, these variation data are more meaningful in terms of potential gain than similar phenotypic variation information for other species. They suggest good progress may be had through clonal selection and testing.

Variation in aspen wood properties has been most recently reviewed by Kennedy (1968) and Pronin and Lassen (1970). It is sufficient to note here that most phenotypic variation studies suggest that prospects for improving fiber properties and specific gravity through breeding are good, but specific estimates of genetic gain from clonal selection are lacking except for those of Buijtenen *et al.* (1959).

While the insects and diseases of aspen are well known (Graham *et al.* 1963), and there is some information on variation and inheritance of pest resistance (Schreiner 1963), data that might be used to estimate gains are rare. A study by Copany (1969) of clonal variation in susceptibility of trembling aspen to *Hypoxylon pruinaum* (Klotsche) Cke. represents the kind of work that will be prerequisite to breeding efforts. This pathogen causes an estimated annual loss of 1 to 2 percent of standing volume (Anderson 1964). Copany surveyed 88 clones on five sites in Michigan, and reported that on a poor site infection ranged from 10 to 83 percent. Study conditions suggested that much of this interclonal variation has a genetic basis. Preliminary observations by Einspahr² indicate that hybrids

² Personal communication with D. W. Einspahr, Institute of Paper Chemistry, Appleton, Wisconsin.

involving *P. alba*, *P. canadensis*, and *P. grandidentata* parentage may be more resistant to *Hypoxylon* than quaking aspen.

The discovery of triploid quaking aspen clones in Michigan and Wisconsin (Buijtenen *et al.* 1957, 1958) led to interest in their fiber-producing merits relative to diploids. Comparison with adjacent diploid trees indicated that triploids were significantly faster growing in one area but not in another. Wood properties were studied in one area; triploids had significantly longer fibers, but there was no difference in specific gravity. A study of phenotypic variation among 20 trees from four triploid clones suggested that differences in growth and wood properties were under moderate to strong genetic control (Einspahr *et al.* 1963). Subsequently, a formal 10-year comparison of two triploid clones with two diploid full-sib families (Benson and Einspahr 1967, Einspahr *et al.* 1968) revealed no significant triploid superiority in growth, form, and specific gravity; triploid fibers were no longer than diploid. In another test, the mean 5-year growth of three triploid clones was about 20 percent greater than that of nine diploid, full-sib families (Einspahr and Benson 1964); the report did not include a statistical comparison, however.

Aspen hybrids of *P. tremuloides* x *P. tremula* have been tested in Europe for several decades and are believed to be distinctly superior to the local *P. tremula*. Larsen (1970) has reviewed the numerous reports of this work; my comments will cover American tests. Ten-year results from the New England screening tests of Pauley *et al.* (1963) indicated that crosses involving Massachusetts *P. tremuloides* females and *P. tremula* males from mid-latitudes of Europe or from Italy performed best, with height growth of 2 to 3 feet per year.

Hybrids of German *P. tremula* and Massachusetts *P. tremuloides* have been compared with local *P. tremuloides* stock in an unreplicated Wisconsin test (Church 1963). At 12 years, the hybrids averaged 24 feet in height and local stock 21 feet. In a 5-year replicated test, Benson and Einspahr (1967) noted that two families of triploid hybrids (*P. tremula* x *P. tremuloides*) grew 3 and 4 feet per year while two local diploid families grew 2.5 and 3 feet. Specific gravity of the triploid families as about 0.4, compared to 0.36 and 0.38 for the diploid. Other reports (Barnes 1961, Pauley 1956) note existence of natural hybrids and suggest their breeding possibilities. In short, hybrids have been successfully grown in the North-Central Region, but large-scale screening and testing will be required before estimates of gain can be made. Some of this work is in

progress at the Institute of Paper Chemistry (Einspahr and Benson 1964).

While no replicated progeny tests in aspen have been reported, Einspahr *et al.* (1967) studied variation in growth and wood properties among 25 full-sib families planted in single blocks on a uniform site. Narrow-sense heritability estimates, based on progeny-parent regression information, indicated moderate possibilities for genetic improvement of growth and moderate to good genetic control over fiber length and specific gravity. Einspahr (1968) has brought together the limited published heritability data, then assumed parent trees were to be two standard deviations better than the population mean, and predicted average genetic gain that might be obtained from full-sib families of these parents. Some of these estimates are presented below:

<i>Improvement characteristics</i>	<i>Estimated means*</i>	<i>Average expected genetic gain (Percent)</i>	<i>Absolute gain</i>
Height growth, ft./yr.	3.00	10	0.300
Diameter growth, in./yr.	.25	11	.030
Volume growth, cu. ft./A./yr.	100.00	20	20.000
Specific gravity, g./cc.	.38	4	.015
Fiber length, mm. (age 10)	.80	6	.050

Systems for genetically improving aspen fiber production could take several forms. Selection of a breeding system and investment level should be hinged on a formal analysis of the relationship between improved material and management, as proposed by Namkoong *et al.* (1971). Perhaps the simplest procedure might consist of roguing existing stands in appropriate situations, a silvicultural measure recommended by Graham *et al.* (1963). Recent information on the nature and development of natural clones (Barnes 1966, DeByle 1964, Garrett and Zahner 1964, Tew *et al.* 1969) suggest techniques for such roguing. Rogued clones might

* Estimated means for 8- to 10-year-old diploid quaking aspen plantations growing at a moderate rate of growth.

be replaced with genetically improved material, or existing phenotypically good clones might be expanded. The results would be a genetically variable and superior stand obtained without the high cost of complete conversion.

I see no major barriers to development to commercial vegetative propagation procedures based on known techniques (Farmer 1963, Benson and Schwalbach 1970); thus selection and testing of naturally occurring clones appear feasible. Because of natural replication, field selection in aspen is probably more effective than in other hardwood species. A clonal selection program might gradually evolve into one aimed at development and commercial use of parents with high specific combining ability. Schreiner (1971) has outlined such a breeding system for cottonwood; it is equally applicable to aspen. Given any of several possible systems, however, it will be important that (1) some large, well-designed tests be established to give badly needed genetic information, (2) field selection be extensive enough to obtain a genetically diverse breeding population, and (3) control populations used in breeding tests be large enough to truly represent natural population means.

OTHER HARDWOODS

Northern breeding programs in birch, oak, and maple, and southern efforts in sweetgum, sycamore, and yellow-poplar have been under way for several years. The impact of these programs on fiber production in the North-Central Region will be variable and will depend on the manner in which improved stock is used. Analyses of the relationships between tree improvement research and action programs and establishment and management plans are particularly important for the fine hardwoods with their relatively long rotation. Improved stock of some sawtimber and veneer species may not be planted at traditional spacings in single species plantations. Rather, this material may be "inserted" in regenerating natural stands at crop-tree densities (i.e., 50 to 100 stems per acre), and cultural methods during establishment may center on these individual trees rather than on the whole stand. Recreational and esthetic benefits may be major management goals in these forests. In such a system, improved growth potential would not be reflected in pulpwood production for at least one rotation. On the other hand, breeding in species such as sycamore and sweetgum is aimed at intensive plantation culture of pulpwood and sawtimber, and genetic gains can be immediately realized.

Information on yellow birch, northern red oak, sugar maple, and white ash is available from provenance tests. In a 3-year-old rangewide birch test in Wisconsin (Clausen and Garrett 1969), there is wide, but apparently random, variation in growth. Seedlings from the best source were twice as tall as those from the poorest one and 32 percent taller than the local Wisconsin stock. First-year heights of northern red oak from southern sources (e.g., Tennessee, southern Indiana, Arkansas) grown in northern Ohio were 30 to 100 percent greater than those of oak from more northern sources (Kriebel 1965). Family (open-pollinated) differences were also prominent, and Kriebel concluded that selection of individual seed parents will be important in improving growth rate. Fourteen-year data from the sugar maple study (Kriebel and Gabriel 1969) also indicated that, in northern Ohio, trees from the central portion of the distribution of the species complex grew better than trees from other sources. Low juvenile 11-year correlations in other tests suggested, however, that early selection for growth is not practical, though juvenile narrow-sense heritability was moderate ($h^2 = 0.28, 0.30$). While no major breeding programs in ash are now in progress, results of Wright's (1962) early provenance tests indicate the existence of southern ecotypes that may outgrow local stock in some portions of the North-Central Region. In brief, information to date suggests that some major improvements in northern hardwood growth may ultimately be based on provenance test results confirming non-optimality of local races (Namkoong 1969).

Sycamore (*Platanus occidentalis* L.) has received most attention in the South as a candidate for "silage" culture (Herrick and Brown 1967). Webb (1970) has analyzed 2- and 3-year data from an evaluation of 64 randomly selected open-pollinated families growing on a good site at 4- by 4-foot spacing. Genetic gain in height from combined selection of the best 5 percent of the population was estimated to be 6 percent. Heritability estimates for third-year growth parameters in this test, which have not been published, suggest that gain will be considerably more than 6 percent.³

A number of well-designed and potentially valuable sweetgum progeny tests have been established, and some reliable estimates of gain in juvenile growth will soon be available. The only heritability estimates published to date are those of Wilcox (1970), based on a population of 40 open-pollinated families from southern

³ Personal communication with C. D. Webb, U.S. Plywood-Champion, Inc., Athens, Ga.

Mississippi. Narrow-sense heritability was 0.25 for 3-year height on a site in central Mississippi, and 0.40 for height on a Gulf Coast site. While Wilcox did not publish data essential to estimating genetic gains, means and family ranges suggest that at least 10 percent genetic gain in growth could be obtained with a selection intensity of 5 or 10 percent. A larger (81 open-pollinated families) test of material from throughout the lower Mississippi Valley is planted on two contrasting sites in central Mississippi, and Schmitt and Webb (1970) have briefly noted some 6-year results. These data indicate the possibility of major gains in growth through a combination of source and family selection in the test plantation. The data so far do not make an encouraging case for mass selection in the field.

Yellow-poplar which should provide some fiber in the southern portion of the North-Central Region, has been subjected to some provenance testing with varied results (for review see Wilcox and Taft 1970), and it is as yet uncertain what sort of gain may be expected from source selection. At least one open-pollinated progeny test has, to date, produced no evidence of significant familial variation.⁴ At present it is apparent that early estimates of gain must await full-sib tests now in progress.

One further comment on breeding in this group of species is appropriate. As Schmitt and Webb (1970) have noted, early data from a number of tests suggest that mass selection in natural stands of most hardwoods will probably not lead to good first generation gains in juvenile growth potential. They recommend that "more effort be devoted to establishing sizable breeding populations rather than refining phenotypic selection in wild populations." I believe this recommendation is particularly pertinent to rapid progress in genetic improvement of fiber production.

CONCLUSIONS

Review of existing published data on variation and inheritance of growth and wood properties in hardwoods suggests that at least 10 to 20 percent improvement in fiber production can be realized in first generation selection. Prospects of indirect improvement through pest-resistance breeding appears good, though based on little data. Because aspens are the predominant pulping species in the North-Central Region, and because they

possess silvical characteristics that are assets to breeding, a major investment in their genetic improvement would be profitable in the long run. Realization of possible genetic gains in aspens and other species will depend on early implementation of judiciously selected applied breeding programs and on increasing improvement-oriented regeneration investments. To ensure wise investment in research and development, early analytical attention must be given to the relationship between improvement programs and the establishment and management of genetically superior stock.

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THE FUTURE SUPPLY OF CONIFEROUS TIMBER FOR LAKE STATES INDUSTRY

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I feel a bit like the onion in the petunia patch today. Here I am, a professional timber beast, trying to tell a bunch of geneticists how to run their genes. However, I do believe that the practical success of the forest geneticists' work is dependent not just on their abilities, but also partly on someone else's knowledge of the real need for tree improvement. So, we will try to pass on to you people some of the understanding that we butchers have for wood markets and availability, both today and to some degree in the near future. Particularly, we will concentrate on the coniferous species.

In the Lake States, we have a total volume of coniferous timber of about 10 billion cubic feet. This figure does not include the timber standing on public lands dedicated to other uses than forest management, but it does include the trees on a lot of forest area that is not available to the timber user. The amount of wood available to the wood-using industries is closer to 8 billion cubic feet than the 10 billion.

At the present time, the actual annual harvest of Lake States conifers for all wood purposes is in the neighborhood of 140 million cubic feet. About half of this wood is cut in Minnesota, the other half in Michigan and Wisconsin.

Of this 140 million cubic feet of coniferous wood that is harvested each year in the Lake States, the paper industry is by far the principal user. About 85 percent of all of this wood is used in the pulp mills. Because of this single overwhelming use, and because I happen to have a better understanding of pulpwood than I do of other kinds of raw wood, from now on my talk will be primarily relevant to the pulp mills.

Let's go back again to the 140 million cubic foot harvest of coniferous wood. Except for jack pine, Lake States conifers are being harvested very conservatively.

The total cut of all species amounts to only 60 percent of the estimated desirable cut. Only two species were higher than this 60 percent figure — jack pine, which is being harvested at an annual rate of 120 percent of the desirable cut, and spruce, which is being cut at a 70 percent rate. The species that has the greatest amount of surplus volume is balsam fir, of which only one-third of the desirable cut is being used (fig. 1).

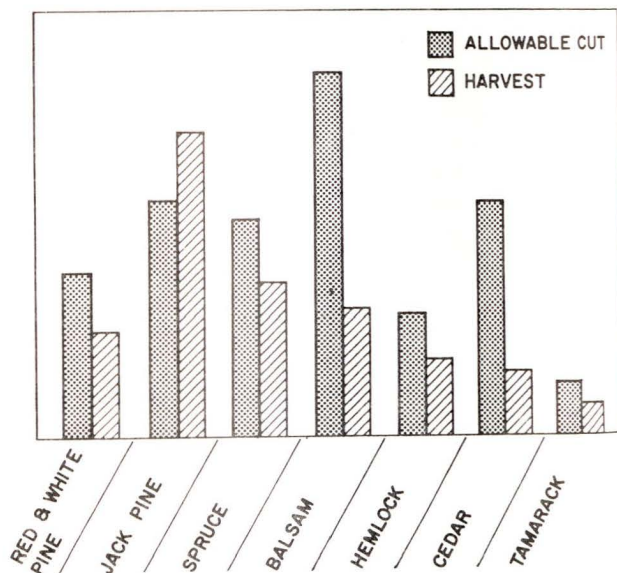


Figure 1. — Allowable cut and harvest in the Lake States.

The use of softwoods in the Lake States has been relatively stable during the past 15 years — varying between 1.6 and 1.8 million cords (fig. 2). However, the use trends of individual coniferous species show a considerably different pattern. For instance, in 1956 spruce was the king species; then over the last 12 years its use has been cut in half. Balsam, also, has been on the skids. But pine use has been climbing steadily, and

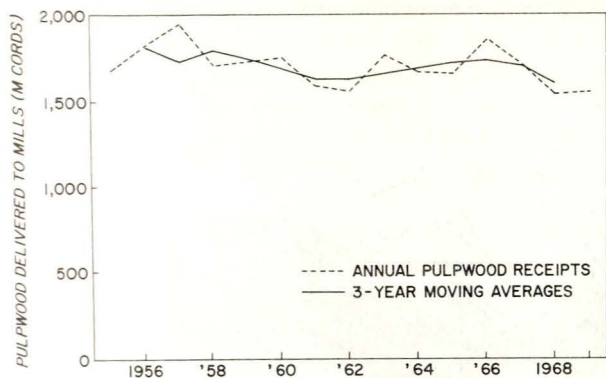


Figure 2. — Trend in use of long-fiber wood in Lake States pulpmills.

chips (mostly pine sawmill waste) have more than doubled in the last 5 years. Hemlock and tamarack use has been quite stable, but they are minor items in the total wood procurement picture (fig. 3).

If my estimates of desirable cut are reliable, and I don't guarantee them, we have at the present time a good surplus of coniferous timber in the Lake States. If there were no restrictions on quality and species, the Lake States softwood-using industries could increase their production by about 80 percent and still be within the bounds of the desirable cut. But these restrictions do exist because of technological, economic, and geographic problems. So, our current situation here is not quite as cozy as the numbers indicate.

The pine pulpwood situation in Wisconsin is a good example of the geographical disproportion between the sites of the paper mills and the location of timber. Wisconsin pine forests are providing the Wisconsin kraft mills with only 35 percent of the pulpwood of these species. This amount of wood is at the limit of the combined desirable cut for all of the Wisconsin pines. Wisconsin mills receive about 15 percent of their pine pulpwood from Upper Michigan, where current harvest of jack pine exceeds desirable cut; and 10 percent from Minnesota, which has some surplus pine. The three Lake States provide 60 percent of Wisconsin's pine needs. The other 40 percent comes from the western States — from the Black Hills and as far away as Idaho. About two-thirds of this western wood is waste material from sawmills — material that was formerly burned (fig. 4).

Now, if this was all that needs to be said about softwood availability in the Lake States, I could go back to my office, sit down in a comfortable chair, and re-

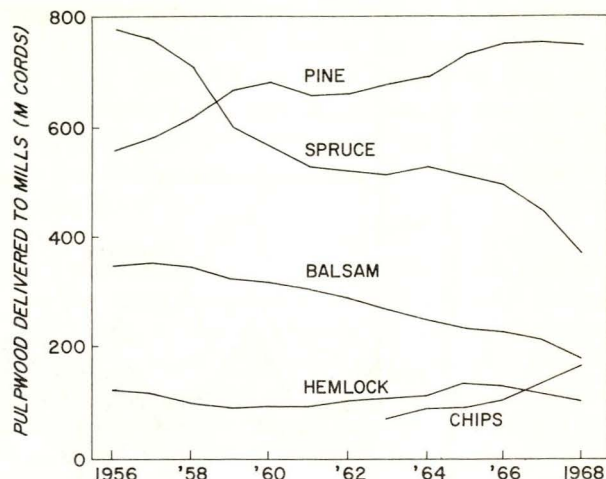


Figure 3. — Components of long-fiber pulpwood delivered to Lake States pulpmills.

mind myself occasionally that the only problems I would have in wood procurement were weather and car shortages; and you geneticists could head for your laboratories and perform all sorts of interesting experiments with no thoughts at all about applying your knowledge to something practical.

But it ain't like that, fellows. For instance, the pine-using mills in the Lake States are dependent upon the western forests and sawmills for 250,000 cords of wood annually. Right now, we are anticipating an increase in western freight rates; an increase that could be so great that it would knock the props out from under these chips as a useful and desirable source of wood. Or worse yet, there is a possible regulation on clear-cutting on the eastern slopes of the Rockies. This could put many western sawmills out of business, and there go our chips again. I am not kidding you about these catastrophes — they are both serious and possible. What do we have to replace our western wood? Principally the surplus balsam and cedar in the Lake States, and these are two species that provide very poor pulp yields.

We have mentioned that there is now a surplus of softwood in the Lake States. But this is not going to be a perpetual premium to the local wood-using industries. There are in sight some factors that will cause changes in the need for coniferous wood and the availability of it.

Let's look at some of these factors that will affect the need for wood. First, the pollution regulations will

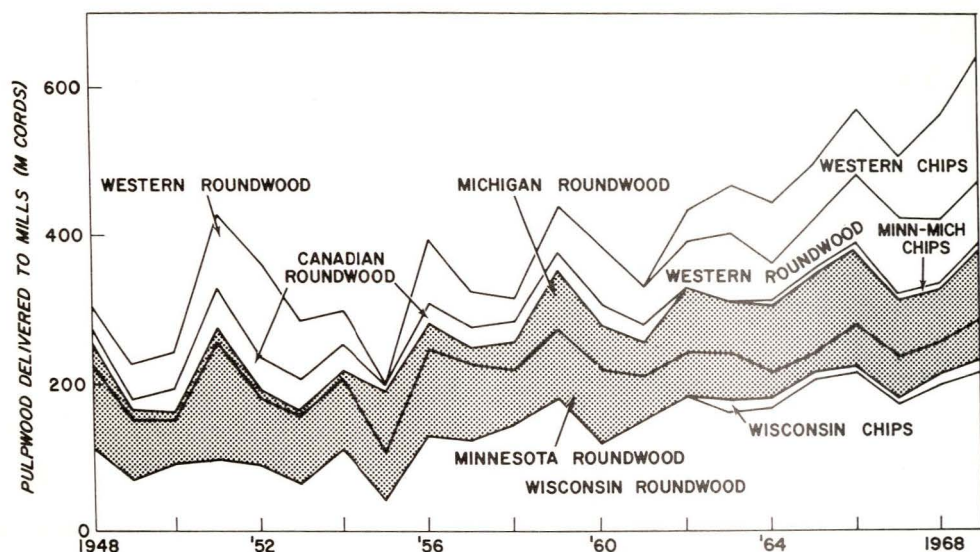


Figure 4. - Sources of pine for Wisconsin pulp mills.

very likely put out of business some of the Lake States pulp mills. We are talking here about some of the old sulfite mills that are principally softwood users. If this does happen, we can expect that most of this abandoned wood will be absorbed by the expansion of other mills.

And then we have the prediction that there will be substantial increases in the national need for the products of the wood-using industries. Certainly, the wood reservoir of the Lake States is not being overlooked — it will provide its share of both softwood and hardwood timber.

These estimates of major increase in wood use appeared to be quite grim when they were first presented. But they appear grimmer when we look at current changes in forest land use; and grimmest when we consider some of the proposals being offered by the environmentalists.

I have seen no figures on the amount of forest land that has been recently withdrawn from timber harvesting in the Lake States but it certainly is a sizable area, and it will become larger. There have been many changes in ownership of private forest lands and much of this will not be available for timber production. Recreation developments by public agencies are being expanded on Federal, State, and county lands that have formerly been considered to be timberlands. The establishment of the Voyageur National Park will swallow a large area of well-managed, private coniferous forest.

The Apostle Islands development is on the edge of one of the large jack pine areas in Wisconsin and the park could put some of this timber in jeopardy. Probably the worst afflictions we have are the newborn environmentalists, ecologists, and preservationists who are proposing the arresting of clearcutting and, indeed, the outlawing of all logging on public lands. Something like this gets serious when presumably perceptive federal lawmakers propose legislation along these lines.

All of these forces are going to cause the timber people a lot of trouble, although the worst of them are not likely to happen to the degree that the proponents are asking.

Now, what can we do about this besides standing here wringing our hands? The first act, of course, is to get involved in the politics of these movements. But there are a lot of other things, too. New technology in the mills is necessary. The paper industry already has increased the reuse of rejected or used fiber and waste materials. Synthetic fibers are being tested. Sawmill and veneer mill equipment is being improved. Better wood handling and processing in the yard and mill is necessary. In a pulp mill that uses 300,000 cords of wood, a 3½ percent loss in the wood system causes the use of 10,500 more cords of wood than is necessary.

What can the foresters do? Better forest management, by all means, and better coordination between management and the research people. When I compare the

correlation of management and research in the Lake States with that in the South and parts of the West, I am amazed at how backward we are. And, of course, we need a better forest management program for small ownerships — a program sponsored by the Forest Service, the States, and industry.

The forest engineers have the task of developing ways of getting better utilization of the wood in the forest. Morbark's Metro-system is a start at this. The bark-chip separation research is another step.

Now, you geneticists sit here sort of quietlike. But don't kid yourselves — we have a job for you, too. You are the people who we expect will provide us with trees that have excellent fiber, very high yield, faster growth, insect and disease resistance, and response to fertilization and irrigation.

I am serious. This is the 10th annual meeting of the Lake States Forest Tree Improvement Committee and I know that the organization has existed about 10 years longer than this period. To my knowledge, we still do not have a superior coniferous tree that will

grow faster than the plain, ordinary, everyday red pine on the proper site. The fault is not really yours; there has so far been little interest in using your skills. Nor is it completely the fault of the forest managers; they have never seriously approached you mainly because no one really had anticipated the situation that lies before us.

I have presented to you my ideas of the problems that the wood-using industries, and our total society, are facing in the availability of coniferous wood. Frankly, I do not feel that we are capable of telling you tree improvers what help you can give us or how you should do it. We do not have the background that you have developed. But I do believe that you can be a real help to us if we can work together. I am not asking for your help in just the development of strains of trees that furnish high yield plantations, but also in other facets of forest management on the millions of acres of Lake States forest land that are not adaptable to the agricultural type of forestry.

If we need a slogan for this job, let's put it this way: You furnish the protoplasm; we furnish the dirt.

WHAT DOES INDUSTRY NEED THAT TREE IMPROVEMENT CAN PROVIDE? SHORT-FIBERED SPECIES

R. B. Valley, *Environmental Control Superintendent*
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Tomahawk, Wisconsin

(Unfortunately, Dr. Valley was unable to submit a manuscript of his presentation at the meeting. The following short summary was prepared by Dr. D. T. Lester and approved by Dr. Valley.)

Dr. Valley emphasized the importance of cost control in industrial forestry. He pointed out the necessity of a systems approach to cost reduction. The Morbark Metro Harvesting System was discussed as an example of technological innovation, with implications covering several facets of the paper production process.

Other contemporary concepts of wood processing, including the long-wood system and the silage system, were mentioned. The trend toward utilization of smaller

trees and shorter rotations was mentioned. Bark removal was noted as a problem in newer harvest approaches and the possible application of genetics to facilitate bark removal was suggested.

Dr. Valley illustrated the decreasing development time between invention and commercial utilization of technological improvements. The holopulping process in which milder digestion increases recovery of usable carbohydrates was presented as an example of modern technological innovation.

TREE BREEDING AS A FOREST MANAGEMENT SUPPLEMENT — ECONOMICAL, SOCIOLOGICAL, AND ECOLOGICAL CONSIDERATIONS

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Hardwoods, Industrial Botany Group
Champion Woodlands Division
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To set the stage for my remarks, I would like to tell a story I recently heard. The top management of a large corporation has just ordered installed two IBM machines in the accounting department. Two middle-aged men — the office manager and his assistant — received the news with some misgivings. They felt that things were progressing well in their office; the accounting was being done adequately at an acceptable cost by a room full of attractive secretaries. As these men viewed the attractive labor force, the manager was overheard to remark to his assistant, "Do we really want to replace all this with a computer?"

There are several aspects of this story that might apply to the many forest industries and foresters: (1) change comes more frequently from top management and usually for economic reasons — less often for sociological or ecological reasons; (2) lower echelon personnel are often reluctant to change because things are satisfactory as they are; and (3) many of us are locked into a stereotyped notion of what an office should be like — or of what a tree, a board, or fiber should be.

It should be no surprise to most of you here when I say that the forest industries have always been interested in tree improvement — in reverse order to what most geneticists consider as tree improvement!

In 1605, Captain John Weymouth of the British Royal Navy nosed his ship into one of the harbors of what is now the coast of Maine. His men cut samples of northern white pine timber, which he took back to England. Captain Weymouth's efforts to inform his countrymen about the quality of the timber in North America were highly successful — especially with the

Royal Navy. Suitable trees in the New England forests were marked with the king's broad arrow and thus reserved for the exclusive use of the Royal Navy (Simmons 1949). Thus began industry's interest in the superior tree!

The search for and the use of the superior tree by industry throughout our history, for legitimate and commendable reasons, also led to the reduction of a desirable genetic base from which to perpetuate our future timber supplies and continues today in many areas. The term for this rather distasteful timber harvesting technique is "high-grading."

Like the office manager and his assistant, forest industries and foresters have responded to and accepted change only when they have found it economically necessary. Large-scale planting was not undertaken until the lack of wood resources became a very real possibility. Innovation in logging techniques came on the scene only when the economics of wood production dictated a change, or because the lack of labor made it physically impossible to harvest a sufficient quantity of wood. The same might be said of tree improvement; acceptance by industry and foresters resulted when it became economically attractive or necessary, or because a potential shortage of raw material required a new approach to plantation management. Dr. Ernst Schreiner advocated and promoted tree improvement and breeding in the New England area 30 to 40 years ago. But industry's tremendous capacity for innovation in utilization standards that would make the plentiful lower grades of fiber more acceptable made tree improvement unattractive then. Apparently, the same situation holds true today. Dr. Schreiner

wrote me “. . . the growth potential of the present forest is sufficient to supply the needs of the north-eastern industries without the need of silvicultural management; taxes are so low that there is no need or incentive to invest in silvicultural or tree improvement practices that could increase the per-acre production of fiber and timber.”

Dr. Robert McElwee of the Virginia Polytechnic Institute, Blacksburg, Virginia, recently wrote me concerning his efforts to set up a cooperative tree improvement program in Maine. “Primarily for the north-east, and I suspect also the Central States, the main hindrance to any meaningful tree improvement is economics. By this, I do not mean that growth rates are so slow that tree improvement is not justified, but rather that land-holding patterns are such that despite sizeable outputs in terms of paper and other products, increased production is not needed and cannot be justified where other production costs also increase. For example, Maine produces sizeable quantities of paper annually as well as many other forest products. Ninety percent of the timberlands in Maine are in eight owner-ships, the largest being 2¼ million acres owned by one company. It is easy to see that with minimal growth rates of ¼ to ½ cords per acre annually, and many sites far exceed this, cut is under growth. Currently in Maine, cut is 60% of growth with natural regeneration and 70 - 90 year rotations. Similar cut-drain ratios are found in other New England states and to me there is no way to justify additional expenditures for any silvicultural practices, including tree improvement.” Does this cut-drain ratio apply to the North-Central Region?

The rather substantial strides in cottonwood culture in the Mississippi Delta came about as a necessity to generate local fiber and eliminate excessive transportation costs. Fortunately, tree breeders and tree improvement specialists had many of the necessary answers to start an operational tree improvement program.

The Texas, Florida, and N.C. State University programs were established in the 1950's at the specific request of industries who came to the universities and asked them to undertake a cooperative effort. To quote Dr. Zobel, Director of N.C. State University Cooperatives, “The Cooperative Tree Improvement Program was initiated in 1956 at the School of Forest Resources at N.C. State University at the request of 11 pulp and paper industries. There are now 22 members. Though the cooperative was initially an industry program, the

state forestry organizations of North and South Carolina and Virginia requested to join and were admitted.”¹ The story on southern hardwoods is similar —

“During the past decade, two factors have largely been responsible for intensified interest in southern hardwoods. First, the quality of hardwoods have been depleted to the point that the demand can no longer be met; and secondly, advance technology within the pulp and paper industry has made hardwood pulp a necessity instead of a liability for the manufacture of specialized products. As a result, the hardwood cooperative was formed in 1963 with 10 charter members... The present membership is 17 industry cooperators and one state forestry organization. Perhaps the greatest impetus to the success of the Tree Improvement Programs has come from the members of the cooperative themselves. Dozens of special studies have been initiated dealing with all facets of tree improvement... These made possible research results and information useful in forest management and mill operations that could not have been otherwise available. The activities of the program can be broadly described as follows:

(1) Applied tree improvement involving seed production, seed orchard establishment, and genetic improvement of trees used in regeneration.

(2) Research on wood qualities, wood variation, and inheritance.

(3) Training of graduate students, accompanied by research activities of a very diverse nature, from theoretical quantitative genetics to seed orchard management.

(4) Basic research on inheritance, quantitative genetics, population genetics, speciation, wood properties, and others. (*Note the priority.*)

“The tree improvement program is a mixture of applied and basic research. Impressive results have been obtained in a short period of time because the program has a central theme: IMPROVE PINE BY WHATEVER METHOD POSSIBLE.

¹ *Tree Improvement Short Course, North Carolina State Univ. at Raleigh, Jan. 1971.*

"The objectives of the hardwood research program differ markedly from those for which the tree improvement cooperative was formed. The reason for this divergence is that hardwoods had been ignored over the past half century while basic information on regeneration, management, yields, and inheritance patterns were being obtained for the southern pines. Consequently, it becomes necessary to derive basic information before any program dealing with hardwood tree improvement can be launched. The basic philosophy of the hardwood research group, however, is to discourage deep involvement in hardwood tree improvement until basic information is obtained."¹ McElwee emphasized this last point with reference to New England —

"The second deterrent (is), despite all the ballyhoo to the contrary, (that) very little meaningful research is available as background with regard to species, site quality, soils data, and other types of information necessary before tree improvement can be meaningfully implemented."

Dr. Ray Goddard of the Florida Tree Improvement Cooperative says: "In my opinion, tree improvement is attractive to industry only when they are involved in large scale artificial regeneration. A few companies will support basic research on a limited scale but widespread acceptance comes when they can see rather direct application to their own needs. In any region with little or no intensive management, or where primary dependence is on natural regeneration, there is little incentive for support of tree improvement." The N.C. State Cooperatives discourage participation unless landownership totals a minimum of 200,000 acres.

So, as in the case of the IBM machines and the secretaries, economies must be apparent and the physical base must be sufficient (but not too large) to justify a change — in this case, tree improvement.

To paraphrase Gertrude Stein: a tree is a tree is a tree. And like the office manager, foresters are reluctant to change because things are progressing as they are. Many of us are content to produce the same old tree in the same old way; we are locked into a stereotyped notion of what a tree is and how we should plant, grow, and harvest it. If we get fiber, fine; if we happen to reap a little grade so much the better. Philip Larson, Chief Research Plant Physiologist, Rhineland, Wisconsin, puts it very nicely (Larson 1972):

"Unfortunately, our forestry traditions regarding the growing, harvesting, and utilizing of trees have not left us in such a favorable position to cash in on the green revolution sweeping agriculture. We are still pretty much dependent upon the tree nature gave us. Even today, our concept of an ideal tree is essentially an imitation of the ideal tree growing in a natural forest. Because of past tradition of timber abundance, we haven't felt the need to really put our imaginations to work to seriously consider how we might alter or restructure a tree to produce more wood."

I have been, and am, an advocate of agri-forestry — the use of agricultural land for the production of fiber and quality along with food crops, if necessary (White 1971). The economical, sociological, or ecological considerations have not made this practical yet, but these pressures may require such intensive use of land in the future. It seems to me that the sooner we embark on an agricultural type of forestry program, the better acceptance we may have by the environmentalists. We may be permitted to utilize our professional knowledge to provide them with the things they will not do without. I see no reason why foresters should not consider growing wood on agricultural ground; the farmer, the horticulturist, and the orchardists do not rely on wildland to produce consumer needs — nor does society expect them to! So all we need now is for Phil and I to get together — he with his nontraditional concept of tree growth, and my heretical suggestion of the use of agricultural land — and we could make a significant contribution to future wood requirements.

Using these concepts, I can visualize tremendous increases in wood productivity, a considerable reduction in land base with consequent savings in taxes, transportation, personnel, and harvesting costs. What might the economies be if, instead of our traditional dependence upon whatever wood fiber is available, a mill could count on fewer species, genetically tailored for the product, and intensively planted, cultured, and harvested? How much does it really cost industry to harvest, transport, and utilize the myriad of species from far-flung, unmanageable holdings? Agri-forestry would permit the ultimate in the utilization of personnel and resources — possibly to the point where fiber could be planted, grown, and harvested on a 24-hour-a-day basis, utilizing all the benefits of fertilization, irrigation, and genetically improved stock. The forest fiber land base could be greatly reduced and yet produce a greater volume of wood. Surplus lands could be devoted to other uses, and we would perhaps be able to

relieve social and ecological pressures while making economic gains. Tree improvement in the South was conservatively estimated to make genetic gains of 5 percent, but indications at this point are that gains are in the 10- to 15-percent range.

Agricultural forestry is not such a far-out concept. In the South we are only a step away, and most of the tree improvement work is confined to lands that are intensely managed and cultured. Historically, much of the present acreage devoted to forestry was agricultural land that came to us because of past abuse and subsequent abandonment. I am certain we cannot depend on this type of salvation in the future!

In 1966 I made a simple survey of five Central States forest industries asking for remarks for the 5th Central States Tree Improvement Conference. In essence, I asked what the present and potential interest might be for the use of improved planting stock. In a nutshell, the replies followed this vein: We cannot economically justify a tree improvement program because we do not own land or contemplate owning land, and the short tenure of farm ownership negates any tree improvement gains that would accrue when providing improved stock to the small landowner. The price that we are able to pay for wood does not justify the farmer's use of improved planting stock, and we lack the basic silvicultural knowledge to utilize improved planting stock even if the landowner were interested in growing timber. All firms agreed that genetically improved stock would ultimately result in reduced costs to the mill due to the uniformity of raw materials.

For this paper, I resurveyed those same companies — I have nothing encouraging to report now. One is no longer purchasing wood; ecologically induced economic pressures dictated other methods of production using another source of raw material. Essentially, the response is as follows: We have an interest, but not an active one. Corporate policy is not to own land. This rules out any long-term program such as tree breeding or tree improvement because we lose control when improved stock is outplanted on lands not owned by our company. Our lack of enthusiasm in sponsoring the tree improvement program is also due to the fact that there are Forest Service Experiment Stations throughout the country who do this type of research, and also to the economic squeeze.

As an employee of one of those mills in 1966, I made this comment (White 1966): "In addition to and concurrently with the development of superior trees.

increased research is required in the mechanics of site preparation, planting, and the culture of trees. The improved stock will be of little value if we do not know how to, or cannot afford to, plant and care for it." My remarks then hold for today — tree improvement must be a total program of mechanics, biology, and economics if it is to be accepted and utilized. As Webb (1972) has pointed out, "Do not expect selection and breeding to make up for poor nursery management, poor seedling handling, and poor planting methods."

To summarize, tree improvement and tree breeding will be utilized by industry when they can be economically justified (don't call us, we'll call you). They will be utilized when raw materials are in such short supply that there is no other recourse (crisis oriented), when landownerships are sufficiently large (not too large) for intensive management, when large-scale planting is the norm rather than the exception, or lastly, if and when sociological and ecological pressures give us no other alternative (help us, what do we do now?!). The surveys I have made and the comments I have heard from others indicate to me that this will be the pattern for the development of a tree-improvement program. Until refined forestry practices are necessary in any given area, the people involved in tree breeding and tree improvement can make the greatest contribution by developing a complete program of applied and basic research that can be implemented when the call comes. A research program must start with the nursery and seed source and proceed through the final crop, always stressing the economic values to be gained. Sell the top management on the merits of tree improvement and work intimately with the field forester. His understanding and acceptance of research activities are necessary to the implementation of research findings. Studies that approach operational size will minimize the stigma attached to the greenhouse and pot culture, looked upon by many field foresters as being entirely impractical and therefore nonoperational.

I would hope that these comments and observations, although rather bleak, will offer you some guidelines for the development of meaningful tree-improvement programs acceptable to the industry.

To conclude, I would like to quote from a letter recently received from Dr. Bruce Zobel:

"The major change in the attitude of tree-improvement programs has been the switch in the attitude of tree improvement as a research effort to an operational level. Now all members

of the cooperatives put it on the level with site preparation, nursery operations, or planting; it is purely operational. Economically, it has been shown to be one of the best investments in forestry operations.

"The theme of our co-ops has been industry participation. Instead of their giving us the money and having us do the work, we ask only for enough funds to do guidance and analysis and the members do the work. This way they feel a proprietary attitude about what is done and they look upon the activities as "our program" rather than "the" or "a" program. If someone has to go out and beg the industry to support a program, it is certain to fail. The need and the enthusiasm must come from the members of the co-op."

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INCREASED WOOD-FIBER PRODUCTION: TECHNOLOGY, ECONOMICS, AND ECOLOGY

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Forest tree improvement is a form of technological change, and it should be viewed as such. The economic objective of technological change is to increase productivity per dollar invested. This is accomplished through selection and breeding for increased growth rates or reduced losses to insects and disease. Programs which yield improved planting stock make forest investments more profitable by reducing initial costs. The empirical evidence to date (e.g., Davis 1967, Lundgren and King 1965) indicates that investments in forest tree improvement can and do pay off, sometimes rather well.

Along with economic objectives, other goals may be achieved through tree improvement. The improvement of ornamentals, particularly in terms of resistance to pests and the rigors of urban environments, leads to increased amenity values. Even this sort of goal may have economic overtures, however, because of social costs for tree removal and changes in property values associated with tree losses.

ECONOMIC ANALYSIS

The analysis of economic benefits and costs follows a well established procedure (Marty *et al.* 1966). The changes in cash flows attributable to a tree improvement program must be estimated, then discounted to the present. A comparison with the investment cost will establish if the program is viable — i.e., benefits at least equal to costs. A comparison with other alternatives will establish the relative priority of tree improvement investments. More sophisticated analyses will consider alternative silvicultural packages of fertilization, weed control, tree improvement, and so forth to search out the optimal combination and intensity of practices.

Uncertainty can be incorporated into such analyses. It is possible, using data such as Lester and Burr (1965) published to design selection and breeding systems that virtually guarantee success. If the costs of such a program are not justified, then incremental analyses can suggest at what point the increase in benefits from reduced uncertainty in a tree improvement program just balances costs. Although operationally useful, a yet broader integration of uncertainty may be of greater long-term use when contemplating a technological change such as a tree improvement program.

TECHNOLOGICAL CHANGE

Our perception of technological change has changed rapidly. A McIntire-Stennis project was established at the University of Wisconsin in 1966 titled "The Causes and Effects of Technological Change in the Forest Industries" (Bentley 1970). The economic viewpoint focused on the role of technological change in the growth and development of national economies. Definition and measurement dominated many research discussions. Unemployment was the dominant social issue, aside from an occasional prophet of environmental doom. All this has been changed by the rapid growth of environmental awareness. Technology no longer is viewed as predominantly beneficial, and many bad side-effects — externalities or costs that are incident on society as a whole — are commonly identified. Many scholarly and popular treatments of these issues, such as Toffler's *Future Shock* (Toffler 1971), have appeared in recent months. The rate of change, scale of impacts, and often unexpected biological and social side-effects give hysterical cries of "ecocide" some credence.

Technological change is the logical outcome of rationalizing man's productive activities. Industrialization, notes Boulding (1964), began with the "turnip."

When agricultural man began to develop crop cultures and plant and animal breeds, and to evolve patterns of rational husbandry, he laid the foundations for industrial man. Later, the harness of energy (mainly coal) provided the major breakthrough for the rational systems of industrial production in the modern world. Forestry has been a part of this phenomenon. For example, changes in mill technology from pitsaw to the modern, all-electric gang saw are illustrative of the general industrialization of developed nations.

Silviculture has been slower to move beyond primitive stages. The general environment was not conducive to change because excess natural raw material, especially in North America, generated low unit values for wood fiber. Long rotations have precluded the rational research and development that took place with hybrids and other rapid advances. A further difficulty faced by the tree improvement people is that breeding for higher wood production is not as easily accomplished as breeding for higher grain production.

We can expect increased interest in intensive silvicultural systems as wood fiber becomes more scarce, causing unit values and the cost of scarce inputs, especially land, to rise. I think there will be a premium on space for timber growing as primary use because of increased demand for recreation lands. As general and specific knowledge increases, more complex systems can be developed at lower costs.

One view on intensive silvicultural systems with which I am familiar was developed by Gordon and Bentley (1970) at the 1969 Wisconsin Forestry Colloquium. Following through their points, we first can note three principles of rational silviculture:

1. Yield is determined by quantity and distribution of photosynthate, and yield is increased by manipulation of these factors.
2. Yield increases require investments, and, other things being equal, the shorter the rotation, the better.
3. Flexibility is always desirable.

In a similar vein, four principles of rational applied research were proposed:

1. Applied research is planned today to yield information in the future. Therefore, the problems that research is designed to solve must be problems of the future.

2. The future is uncertain. Therefore, applied research must be oriented toward producing results with built-in flexibility (breadth of applicability).

3. Applied research must be coupled in real time to productive systems, to provide useful feedback from practice to research. More simply said, research must be goal-oriented, and the goal must be a production goal (e.g., profits).

4. In this technological age, the productive system must be predicted at least in part upon the capabilities of applied research to aid it.

These principles were combined into the following conclusions:

1. Short rotations are necessary to reduce capital carrying costs, allow research results to lead to rapid results in the field, and provide frequent opportunity for change in land use.

2. Intensive care of dense stands will enable rapid vegetative coverage of the site, and maximum photosynthetic activity with fertilization, pest control, breeding, mechanical planting, harvesting, etc. to avoid biological or technological bottlenecks.

Achievement of this type of system, we concluded, will require a research team approach with a systems viewpoint. As almost an afterthought, perhaps prompted by our declaration of a systems view, we have the following paragraph of warning:

Another point should be made regarding a systems approach to more rational silviculture. Agriculture has not done a very able job in recognizing the adverse effects of its rationality. Some of these, such as site deterioration through intensive fertilization, watering, and cultivation, directly affect the producer. Other effects, particularly those associated with monocultures (hard pesticides, for example), may have greater social costs than private costs. A true systems viewpoint will perceive and incorporate these difficulties as well as the more pleasant and profitable advantages of modern plant culture.

FOREST MANAGEMENT

These ideas, together with a definition of the forest management process, lead to an important conclusion. The processes of management are:

1. *Perception.* — The problem-finding step — being aware that a problem exists and what it is.

2. *Planning.* — Specification of the problem for analytical purposes, information gathering and analysis, evaluation and decision — the problem-solving step.

3. *Implementation.* — On-the-ground activities to carry out planned decisions — the *administrative* step.

4. *Feedback.* — An ongoing step that relates all other steps. It is especially important if new perceptions of problems are to be an improvement over previous problem conceptions. Feedback is a dynamic activity, and it is antithetical to an equilibrium view of the world — economically or ecologically.

Most researchers specialize in the analytical component of problem solving. There has been a conflict between analytical problem-solvers and land managers for some time (Macon 1967). Planners think problems are solved by evaluation and decision; implementers recognize that nothing is changed until activities are accomplished. Feedback mechanisms often are bad — fire control is the only forest activity with a highly developed feedback learning mechanism — and effective learning devices should be built into all planning-implementation systems. It is in problem perception, however, that we are the weakest. Perhaps it would be better to describe this weakness as the most incomplete step in forest management.

PROBLEM PERCEPTION

If our understanding of problems is weak, too often we solve the wrong problem, then implement the wrong solution, and follow up with a weak feedback mechanism that does not identify our basic mistakes in perception. We need a broader viewpoint than industrial rationality to resolve this difficulty. The principles that Ferkness (1969) recently outlined provide the basis for going beyond industrial man to a philosophy of "Technological Man" — really "Ecological Man." These points are really an ecological viewpoint composed of three interrelated ideas:

1. *Naturalism.* — Man and his management of the forest resource as an integral part of nature — emphasis on natural, not physical complexity.

2. *Holism.* — The systems viewpoint (as contrasted with systems analysis) that all components of a system are interrelated and only have meaning in context of each other.

3. *Internal self-determinism.* — Focus on internal creation of the system — the forest ecosystem with man included — rather than external, usual unexplained forces creating the system.

With this broader perspective of "Ecological Man," we can construct silvicultural systems, including needed tree improvement programs, which are *ecologically* and *economically* sound. To take a few problem areas, we must be concerned with:

1. *Genetic changes*, especially a narrowing of gene pool. How might such changes affect ability to resist much more rapid population processes in pathogens and insects?

2. *Ecology of artificial monocultures*, including effects of fertilizer, pesticides in nutrient and biochemical cycles.

3. *Is the intensive forest flexible*, as we suggest, in terms of real human wants, or is the more "natural" forest sounder?

Answering such questions might lead us to conclude that medium intensity management may in fact be superior for agriculture and silviculture. Such systems would have fewer negative externalities — i.e., pesticides, mineral leaching — and would have more positive externalities — e.g., amenities, ecological diversity.

Consideration of such issues does not mean capitulation to the current environmental evangelism — especially voices that reflect naïve or erroneous understanding of forest ecology and economics. It will contribute to the development of sounder strategies for maintaining or improving all qualitative aspects of our life. A broad perspective, while yielding more complex problem concepts, will lead us to attack and solve the real problems. A narrower view of forest production will defeat current timber production efforts because of uncertainty about what facts and opinions we will face in the future. Economics and ecology are, in fact, quite compatible — the discounted value of an ecological disaster, even if it is in the distant future, still is high present cost to contemplate when designing rational, but narrowly conceived silvicultural systems.

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INFORMAL GROUP DISCUSSION

Editor's note: The morning's presentations were discussed during the afternoon by three groups, each group discussing one of the morning's three topics. Summaries of the discussions, prepared by the discussion leaders, follow.

TOPIC I

What can we achieve through tree improvement?

(Papers by J. W. Wright and Robert E. Farmer.) Discussion Leader, Hans Nienstaedt, North Central Forest Experiment Station, USDA Forest Service, Rhineland, Wisconsin.

The discussion not only considered what can be achieved through tree improvement, but also how the results of tree improvement can be put into use. The following questions were raised: Is industry ready and willing to use the information now available? Have tree breeders been too reluctant to make recommendations involving a moment of risk? Do tree breeders have to bear the entire burden of testing prior to release of improved types? How do we mass-produce improved seed?

A strong undercurrent in the discussion was the feeling that genetic researchers and tree breeders, on one hand, and the practicing foresters, on the other, have failed to communicate. Researchers and breeders have been "ultraconservative" and have qualified results and recommendations to such a degree that the man in the field has turned away with the attitude, "He has nothing now, I'll come back later when something has turned up!"

It has been stated that if the plant breeder strives for perfection, he will never develop a usable product. The breeder must be willing to take risks, perhaps like the weatherman — stating the risk as a probability. Industry representatives participating in the discussion indicated that their management would be willing to assume the risks involved. It was emphasized that without taking risks, we would, in fact, achieve a certainty — *the certainty of no improvement*.

If forest managers have questioned the credibility of tree breeders, the breeders have at times reciprocated

when viewing the activities of forest managers. It was pointed out that foresters engaged in seed procurement and seedling distribution not infrequently jeopardize their own programs by ignoring common knowledge regarding the adaptation of seed sources and seed zoning.

The breeders of crop plants rely on the farmers for much of their testing in production situations. Tree breeders should do the same and would find industry willing to cooperate. But this will require advanced planning. The time to plan with industry is when the test is seeded in the nursery, not 2 to 4 years later when material is ready for field planting.

Methods of reducing risks when outplanting partially tested improved material was also discussed. One approach is to develop reliable predictors of growth. Work is now in progress on potential predictors such as isoenzymes, DNA, other constituents of the plants, and defined processes of growth. An understanding of growth components may not only lead to the development of reliable predictors and reduced risks, but may lead to greater growth gains through breeding for specific combinations of growth components. Another suggested way of reducing risks would be to increase the number of species planted. Rather than relying on the potential improvement of one species, several promising products of tree improvement involving a number of species could be planted. This approach, particularly, would require cooperative tree improvement efforts, because it is doubtful that one company would have the funds for breeding programs involving more than one or two species.

In the past, tests of genetic material have essentially consisted of wildland plantings; they have involved a minimum of ground preparation and subsequent control of competing vegetation, and standard spacing such as 6 by 6 or 8 by 8 feet. Future silvicultural practices will, undoubtedly, be more intensive. They may involve more thorough ground preparation and control of competing vegetation, the application of fertilizer, and

What does industry need that tree improvement can provide? (Papers by J. W. Macon and R. B. Valley.) Discussion Leader, Dean W. Einspahr, Institute of Paper Chemistry, Appleton, Wisconsin.

spacings that will facilitate mechanized harvesting. The goal will be greater production per acre and shorter rotations. It was suggested that tree breeders, in their tests, should use the plantation management practices in the future. However, one participant pointed out that in the majority of tests conducted so far, genotype x environment interactions have been of a type that would indicate that genotypes good on one site would be good on all sites. In other words, the genotypes that are good under the present intensity of management would also be good under the management practices of the future. Be this as it may, it would be desirable to demonstrate through our genetics testing the degree to which improved material can increase production under optimized growing conditions.

Mass production of improved seed was discussed at length. It was emphasized that research costs in the region have almost exclusively been borne by the public, because research has been carried out by universities and federal organizations. Mass production of the improved material for commercial use generally is not the responsibility of the research organizations. It will require developmental programs. The question is — who will be responsible for the organization and funding of such programs?

Industry representatives in the audience indicated that industry is ready to become involved either independently or through cooperative efforts. It was also suggested that the State departments of natural resources would be in a particularly favorable position to organize such programs, and would be able to obtain federal financing.

In summary, the discussion emphasized the following:

1. Tree breeding only becomes meaningful when mass-produced stock becomes available for commercial plantings.
2. Geneticists and tree breeders have preliminary information for several species and the information should be put to use now. Some risks would be involved in using this material.
3. Industry is willing to assume these risks, and some industries are definitely willing to get started now.
4. Mass production of improved material will require cooperation involving Federal, State, and private agencies.

The discussion leader briefly reviewed the views of the two speakers and pointed out that John Macon had presented his views on current and future use of conifers in relation to the current and future conifer inventory of the Lake States Region. He expressed concern regarding our ability to meet future pine fiber requirements and indicated the need for forest genetic programs that stressed: (1) improved growth rate, (2) improved wood quality, and (3) the need for species that respond to fertilization and irrigation and other intensive forest management practices and, (4) a maximum amount of cooperation between research and management.

Dick Valley, on the other hand, expressed the need for hardwood species that: (1) plant easily, (2) are well adapted to all environments, (3) have rapid cellulose production rates, (4) are compatible with low cost harvesting systems, and (5) have low bark adhesion, easy pulping, and longer fiber structure.

Dr. Valley, like John Macon, stressed the need for cooperation between forest geneticists, forest managers and mill managers in order that a satisfactory "complete" system be developed.

Following the summary, the groups were asked for "feedback" regarding their views on the topic. Bill Bromley (American Pulpwood Association) led off the discussion with a word of caution in which he stated that he hoped the forest geneticist would not go overboard and stress short rotation materials to the exclusion of other types of forest products. Bill expressed the need for everyone involved to consider the "multiple use of wood as well as a multiple use of land." Dick Valley, in defense of his comments in the morning session regarding intensive management-complete tree harvesting systems, indicated he did not feel that such a system could be used on all lands but instead felt that approximately one-third of the land area would be used primarily for recreation, one-third managed using conventional forest management techniques, and that the intensive management system approach would

be confined to those areas near the mill best suited for such an approach.

Dave Dawson, in expressing his views on the intensive management subject, pointed out that intensive management of certain areas would free other areas for alternative uses. Intensive management, Dave felt, should be viewed as a supplement to multiple-use rather than as a deterrent.

Mr. Gordon Connor and Fred Ziemann expressed similar points of view and suggested that we should be genetically improving species for future production systems but, more importantly, we should be getting the most we can out of our present forests by improved utilization (chipping tops, etc.) and through fertilization of hardwood stands. Total tree harvesting systems were discussed and the point was made that should these harvesting methods become accepted, proper consideration must be given to how we plan to revegetate these areas. Mrs. Gordon Connor stressed the importance of educating the public regarding the point that good forest management is good forestry and good conservation.

Hans van Buijtenen and others including Mark Holst and Fred Ziemann expressed the concern that because of the time lag involved (as much as 40 years) in genetic improvement, paper industry needs could easily change before appropriate gains were obtained. A discussion of this aspect of tree improvement indicated that the key to the problem was to build a reasonable amount of flexibility into any genetics program so that the trees being developed could be used for other purposes (sawtimber, ornamentals, etc.) should industry needs change.

Tom Rausch and Clyde Hunt commented that progress in the Lake States Region was not as slow as the discussion might indicate. Tom indicated that the State of Wisconsin was presently using results of genetic studies to determine regions from which they should purchase spruce seed for nursery production. Also, Tom indicated that red pine seed production areas had been established and red pine seedling seed orchards were being developed by the State of Wisconsin in cooperation with the University of Wisconsin. Clyde Hunt commented that we are beginning to recognize the requirements of the type of tree that is needed to make the total tree system work. He also felt that we presently have genetically improved materials that meet the requirements and all we need to do now is to plug these materials into the system. Clyde stressed the use of *Populus* species, and the use of a mixture

of clones; he commented that aspen, because of its flexibility (usefulness in recreation, lumber, and pulp), its site requirements, and growth habit, could be expected to work well in "the system." Jim Hensel along with the discussion leader commented further on the "total tree concept," stressing the need for demonstrating what our presently available improved materials can do on the areas being harvested via the total tree concept.

From the group came the comment that we have been working in forest genetics in the Lake States Region for a considerable time period, and what we now need are action programs to make genetically superior seed and seedlings available to industry and the public. Another comment from the floor referred to John Macon's concern about the low specific gravity of balsam fir. The question was raised about the possibility of improving specific gravity and other juvenile wood properties of such species as red pine, jack pine, larch, and balsam fir. Comments from several geneticists who had worked with these species indicate modest gains (± 10 percent) could be obtained. Following a rather lengthy discussion on improvement of juvenile wood characteristics, Clyde Hunt, John Macon, Dick Valley, and Hans van Buijtenen reviewed the problem of what fiber characteristics are wanted by the papermaker. It was pointed out that the fiber characteristics desired depend upon the end-product requirement, and that to produce the variety of products now being manufactured by the paper industry, anywhere from six to 30 basic fiber types would be required. It was pointed out, however, that by separating springwood from summerwood and/or mature wood from juvenile wood, more than one fiber type could be obtained from the same tree.

Dick Valley discussed the importance of fiber characteristics to end-product properties and production speed, and it was concluded that fiber properties (fiber length, flexibility, etc.) should be considered for improvement both by genetic and silvicultural techniques. Tom Rudolph, among others, emphasized the need for producing trees that will give greater volumes of wood per acre; as far as wood quality is concerned, perhaps the most important contributions that could be made would be to give the papermaker a uniform quality raw material with certain well-defined properties that would then allow him to optimize pulping and papermaking conditions.

Tom Rudolph reemphasized the comments of several of the symposium speakers who indicated we need a

balanced approach in which research effort is expended toward both tree improvement and forest management methods to get the improved materials into the field. Tom also felt that in many instances we are not testing our materials under the type of field conditions that they should ultimately be growing under, and that due consideration should be given to this aspect of improved-tree evaluation.

The final topic before adjournment was the difficulty encountered by the various research groups in obtaining adequate funding for tree improvement and testing of improved materials. Holst, Garrett, Macon, and Einspahr each commented regarding funding problems, particularly as they pertained to the Lake States Region and the Northeast. Lack of adequate funding was of primary concern. The North Carolina State Cooperative program was described as a good one which has the desired flexibility. It was pointed out, however, that company size, forestry staff, and land-holding patterns in the North and Northeast differ from those in the South, and that some type of cooperative program in which several companies pool their resources to produce improved seed and seedlings would be more appropriate.

The discussion of the topic "What does industry need that tree improvement can provide?" stressed the following needs:

1. Action programs that provide adequate numbers of improved materials for the public and industry.
2. Rapid-growing hardwoods and conifers that have been tested for site requirements.
3. Continued emphasis on improvement of hardwood fiber properties.
4. Increased emphasis on improving the juvenile wood characteristics of tree species, particularly conifers.
5. Forest genetics research programs with built-in flexibility so that as paper industry needs change, the materials involved will still be useful.
6. Balanced programs that not only provide improved trees, but the "know-how" to establish and manage these improved materials.
7. Trees that are well adapted to future highly mechanized harvesting systems and that fit into the

"complete system," which considers establishment, growth, harvesting, and manufacture of the final product.

It was also generally agreed that there is a need to establish lines of communication, cooperation, and feedback between forest geneticists, forest managers, and pulp and paper management so that a suitable overall production system can be developed.

TOPIC III

Tree improvement as a forest management supplement. (Papers by Gordon White and William R. Bentley.) Discussion Leader, J. Douglas Brodie, Department of Forestry, University of Wisconsin, Madison, Wis.

The session leader introduced the topic with a brief summary of what he, as a nontree breeder, had learned from the morning session. Basically, tree breeding can offer improvement in two broad categories — quantity and quality. In terms of quantity, tree breeding will result in greater growth rates that will benefit forest management in two ways: (1) greater yields per acre, and (2) shorter rotations. The quality dimension can be divided into three parts: (1) the physical properties of the tree that enhance its desirability at the mill, such as fiber, bark, and chemical properties of the wood, (2) the form and stand characteristics and properties of the tree that enhance harvesting, and (3) the growing or tending properties of the tree, including biological resistance, tolerance for adverse site and climatic agents, and pest resistance.

Timber management is a long-term investment activity that is fraught with uncertainty. Initially, attention is likely to be focused on protection or stand improvement in existing stands. Terms such as "intensive management" or "high-yield silviculture" imply not only a systems approach to forest management but also shorter time periods for production, afforestation, and reforestation. Certain experimental maximum fiber production projects in the South have suggested the term agri-forestry. This might suggest that forestry at present, similar to agriculture in the past, may be able to make substantial strides forward through plant breeding.

Professional forestry during the past 70 years, by crying out against the wolf of scarcity, has instituted

substantial gains in fire protection, harvest control, reforestation, and afforestation. Economic scarcity of timber products within the next three decades appears to be a real possibility, without substantial increases in forest productivity during the interim. Such scarcity could be expected to develop sooner in local regions and for particular species. A conference such as the present one addresses itself hopefully to the real possibilities of forest tree improvement and perhaps somewhat ruefully to the seeming inertia in the adoption and application of modern tree breeding techniques in the north-central States.

In discussion the group decided that the production demand for improved tree stock will not be realized until scarcity or incipient scarcity occurs. The demand will appear first in short-rotation, reforestation-oriented operations. It is beginning to be felt in the Lake States now in seed source certification, nursery practices such as culling, and in the establishment of seed orchards. Part of the problem in the Lake States appears to be that the demand for the tree breeder's talents does not seem to be as intense as in other parts of the country, such as the South. Discussion indicated that conditions are different in the Lake States than elsewhere. In the South, the overhead of landownership has provided a spur to efficiency and to the adoption of high-yield management practices, including the application of tree breeding results. Such conditions are currently lacking in the Lake States, and the discussion focused on the question of what tree breeders should be doing while awaiting the development of demand. It was agreed that the Lake States tree breeding establishment had not been, and would not be, idle during this interim. As in the past, they should continue to develop a wide diversity of plant materials and stockpile knowledge and techniques; in the absence of widespread application of results, they might continue to develop and

question the type and extent of future demand for improved trees.

It was agreed that the efforts should not be focused solely on basic research. There is, and will be, a real demand for applied research that will satisfy immediate needs once improved forest plant materials are required. The question was raised as to why Lake States industry found it impossible to support basic tree improvement research. An industry participant replied that interest on the part of industry was great; however, support for tree improvement research was impossible for a number of reasons. At present in the Lake States, growth of trees on industrial land is much greater than the current or prospective rate of drain through harvest. It was stated that if you are planting extensively, then you can use a better tree; if you aren't, you can't.

Attention should also be given to the communication of results that can be used and applied now to stimulate demand for future tree-breeding improvements. One of these techniques for immediate application would be the identification of superior trees for use even under natural regeneration systems. Small improvements spread over large-scale acreages can count significantly. Efforts that must necessarily be based on tree planting will be spread over a much smaller area, at least at present. The importance of the effort going into seed and tree improvement shouldn't be minimized; however, natural regeneration and selection systems should be considered as well. The implied correlation between genotypic and phenotypic characteristics suggested by the application of tree breeding expertise to natural regeneration systems was questioned. Discussion from the floor indicated that while the magnitude of this correlation is generally unknown, it could at least be assumed to be positive; therefore it is better to apply phenotypic selection in natural systems than no selection whatsoever.

PRACTICAL BREEDING OF COTTONWOOD IN THE NORTH-CENTRAL REGION¹

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More than 20 years ago Scott Pauley (1949) designated the genus *Populus* as the "guinea pig of forest-tree breeding." This designation is still appropriate as evidenced by the steady, almost overwhelming, stream of publications related to the genetics and breeding of poplars. A good indication of the scope and depth of genetic work with poplars can be found in the recent review of poplar breeding by Muhle Larsen (1970) and discussions of cottonwood genetics and breeding by Schreiner (1971) and Farmer and Mohn (1970). These reviews cover a variety of research and breeding activities at widely dispersed locations and support the contention that our knowledge of poplar genetics is comparable with that available for any other group of forest trees. My assignment is to relate this knowledge to the "practical" breeding of cottonwood (*Populus deltoides*) in the North-Central Region. While I will concentrate on eastern cottonwood, the biology of the genus *Populus* requires consideration of the other species and hybrids commonly called poplars. Aspens will not be considered.

For a breeding program to qualify as "practical" it must be undertaken with a high probability of producing improved material within a reasonable time. At this meeting Farmer (see page 9) has pointed out the strong evidence of potential for genetic improvement in cottonwood. In addition, the experience of Europeans in poplar breeding (FAO 1958, Muhle Larsen 1970), the progress in poplar hybridization in the Northeast (Schreiner 1949, 1950), and the work with cottonwood in the Lower Mississippi Valley (Farmer and Mohn 1970, Mohn *et al.* 1970) all indicate that we can design programs for this region that will rapidly produce genetically improved poplars (cottonwoods, balsam poplars and their hybrids). While additional genetics work is needed to design optimum

programs, neither a lack of knowledge nor a lack of biological potential is a major stumbling block to the initiation of practical breeding in our region.

"Practical" in breeding implies a use for the product, not just the production of biologically improved material. The reason many forest geneticists in this region take a "guinea pig" approach to work with poplars is that poplars aren't planted extensively enough to justify breeding programs. We can speak about practical breeding of cottonwood at this meeting because our theme is the future and there are strong indications that our future may include a demand for improved poplar planting stock. Poplars can have great value as a crop on the "fiber farms" Westell (1969) foresees developing in this region. They are ideal for use with systems of intensive cultivation on selected sites because: (1) they have the potential for rapid growth essential to making highly mechanized "forest farming" pay, (2) we have the technology for effective utilization of their wood, and (3) a wealth of experience has been acquired that can be used to quickly develop plantation management systems suited to our region.

The development of intensive culture of cottonwood or poplars in this region will probably be centered on some of the 4 million acres of excellent and good quality elm-ash-cottonwood sites Dawson and Pitcher (1970) reported. It can logically be expected to follow a progression from experimental plantings to pilot-scale plantings to commercial plantations such as McKnight (1970) described for the lower Mississippi Valley.

At this time most of the work in the North-Central Region is in the experimental stage. We've been in that stage for a considerable period of time. For example, a 1913 USDA publication includes a photograph of a fine 12-year-old cottonwood plantation in southern Minnesota with trees of pulpwood size (Williamson

¹ Published as Journal Series Paper No. 77652 of the Minnesota Agricultural Experiment Station.

1913). Records of hybrid poplar plantings go back at least to 1888 and other test plantings have been established periodically (Rudolf 1948). Results have been mixed, but encouraging enough to sustain interest.

The next step will be the development of systems for cultivating poplars in our region on a large scale. This means we must define the elements of these systems from planting to utilization and bring them together in a workable package. This task will take the combined efforts of silviculturists, field foresters, utilization specialists, and others. Ironically, in this critical step in the development of viable breeding programs, the role of the forest geneticist is small.

TESTING COTTONWOOD SELECTIONS AND POPLAR HYBRIDS

The immediate task for forest geneticists is the identification of materials suitable for use in small-scale experimental or demonstration plantings. The goal is to find materials that will perform well; the guideline should be reliability based on sound biological reasoning or past testing. This step is analogous to the delineation of seed collecting zones or seed source recommendations in other species. It is most critical in poplars because a relatively small number of "well-traveled" genotypes, not seedlings of a local origin, have traditionally been used for planting stock. Often these materials are planted because they are available and not because of their performance in local tests.

The task is complicated by the variety of materials available. In our region the native cottonwood can be considered. *Populus balsamifera* is also native to a part of our region and the potential for fiber production under plantation conditions of this species is unknown. In some Minnesota tests *Populus nigra* and *Populus trichocarpa* have grown at impressive rates and these species, along with other exotics, are candidates. Hybridization occurs between many *Populus* species naturally and nearly all can be artificially crossed (Muhle Larsen 1970), adding many hybrids to our list. The complexity of species and hybrids is compounded further by the capacity for asexual propagation common in poplars. Individual genotypes are used on a wide scale and the clone as a unit of genetic identity increases the number of options almost to infinity.

The task of making recommendations becomes manageable when two biological considerations come into play. The first of these is the need to avoid excessive

genetic uniformity. Schreiner (1959) and others have stressed the increased danger of disease and insect attack in monoclonal plantations. To maintain genetic diversity, planting of individual clones should be avoided, and recommendations should only consider mixtures of at least 15 to 20 genotypes. Seedlings can also be used to ensure genetic diversity and this may be the only reasonable alternative when propagation difficulties are encountered.

The second consideration is the need to use materials that are well adapted to the conditions under which they are to be grown. To ignore this factor invites poor growth or excessive injury due to climatic stress, disease, and insects. Because the trees we plant must be adapted to the planting site, our choice will be among materials that have been adequately tested in the locality, and selections from local wild populations.

In some parts of the region work with cottonwood or poplars has progressed to the point where a group of high-quality clones can be identified, but in many areas the results of tests have been negative or inconclusive. There the local wild populations will be the best source of planting stock. Smith (1968) recommended this sort of alternative after reviewing experience in poplar planting in Canada, and Maisenhelder (1970) recommended the use of selections from local populations of cottonwood in the South, after a large array of hybrid materials failed to perform satisfactorily.

Cottonwood is the logical species to plant in most parts of our region. The simplest approach is to collect and use cuttings or seed from good stands. Some sort of phenotypic field selection may be practiced in an effort to get genetic improvements. Such selection should be based on genetic information — e.g., heritability estimates and character correlation — and on a critical assessment of characters to identify those with economic importance. Little information is available concerning the effectiveness of field selection for specific traits. However, traits that are known to be under strong genetic control, such as *Melampusora* rust resistance (Jokela 1966) should be given more weight than traits such as growth, for which the effectiveness of field selection is questionable (Farmer 1970, Mohr and Randall 1969). As a general rule it is best to choose trees that are outstanding for one or two economical important traits and satisfactory in other respects.

The number of trees selected in the field should be adequate to ensure genetic variability in the planting

stock. If the use of selection directly via asexual propagation is anticipated, an excess should be selected because a large proportion of the genotypes will be eliminated in the nursery as a result of propagation difficulties. Muhle Larsen (1970) reported a range in rooting success of cottonwood clones from 0 to 100 percent. Work with cottonwood in Mississippi has been plagued with propagation difficulties, causing Maisenhelder (1970) to recommend restricting field selecting to 3- to 5-year-old trees when developing a source of planting stock.

The procedures used in obtaining stock for immediate planting will vary greatly from locality to locality. Past testing, decisions regarding the best way to propagate, and the resources available will all be determining factors. No matter what procedure is followed, the emphasis always should be on obtaining reliable materials quickly for use in developing effective systems of plantation establishment and management.

BREEDING OF POPLARS

Cottonwood Breeding

Actual breeding will come in response to the demand for improved materials associated with increased planting. In designing breeding programs the first step will be the establishment of clearly defined goals. All aspects of the cultural systems in use, from planting to utilization, should be considered; priorities should be developed so efforts will be concentrated on making changes that have an actual impact on productivity.

Genetic improvement, as in other species, has two phases: (1) the production or definition of populations with which to work and (2) the selection of superior materials from these populations. In developing working populations, the objective is a high frequency of favorable genes or gene combinations.

In practice, materials with which to work can be expected to accumulate with astonishing rapidity. Identification of the superior materials is more difficult and time consuming. Large backlogs of promising, but unproven, materials are characteristic of poplar work. Evaluation in the nursery can be used to cull out material with poor propagation characteristics, susceptibility to pests, or obviously low vigor. However, experience with cottonwood in the South suggests that the most substantial gains will come from selection based on adequate field testing (Mohn and Randall 1969). Emphasis in a practical breeding program should be on

the establishment of such field tests using enough materials to permit the intensive selection necessary to obtain substantial genetic advances.

It is probable that asexual propagation will be used in cultural systems developed for this region and that clonal tests will be the basic tool in genetic evaluation. Clonal tests should be established and maintained using the same cultural techniques as are used in commercial plantations. Testing on several sites will most likely be required (Randall and Mohn 1969) and final selection should be delayed until trees have been tested for a half-rotation (Schreiner 1971). Relatively few ramets per clone are needed. Schreiner (1971) recommended from 10 to 20 per site and this number was adequate in the Stoneville tests.

Concentration on field evaluation means that breeding programs should be designed so several hundred new clones are placed in field clonal tests annually. The acreage required is substantial but can be reduced by establishing an initial test on a single site with a large number of clones, conducting a preliminary evaluation at perhaps one-quarter rotation age, and then testing only the better clones on other sites. The cost of large-scale field testing can also be reduced by other means. In the Forest Service program at Stoneville we were able to place several hundred clones in a field test at a low cost by combining our test with a commercial planting. The arrangement was most satisfactory to the cooperator (who cultivates and maintains the planting) because he will harvest the test along with the rest of his plantation.

In this region I recommend that the first series of clonal tests be aimed at evaluation and selection of clones from local cottonwood populations. This will ensure that materials selected in the early stages of the breeding program are well adapted to local conditions. Phenotypic selection can be used to obtain the candidate clones; but since the emphasis is to be placed on relatively large numbers of clones, its intensity will be relatively low. If the pollarding and nursery propagation techniques described by Schreiner (1971) can be used effectively, selections can be placed in field tests directly. If not, the most practical alternative is the cloning and testing of open-pollinated seedlings from the plus-trees. Materials currently being used as planting stock should be included in these, and all tests, as a basis for comparisons.

The process is a kind of mining of the natural population that should not be carried out indefinitely. The

effectiveness of selection in terms of usable gain per unit effort will decrease as additional materials are tested. A limit should be set and when it is reached the emphasis shifted. A reasonable approach would be to continue establishing tests until 1,000 clones are being evaluated. If the top 5 percent of the clones tested were selected, this phase of the program would yield a group of 50 clones suitable for use in commercial plantings and as a base population for further breeding.

After adequate numbers of local cottonwoods are under test, new populations that have a high probability of containing favorable genotypes should be located or created. Results of provenance tests, such as those coordinated by J. J. Jokela of the University of Illinois, may indicate that nonclonal populations of cottonwood are worth considering. In Minnesota, for example, a high proportion of the exceptional phenotypes in a 6-year-old provenance test are of a Missouri origin. We, in Minnesota, should consider practicing selection in populations obtained from central and northern Missouri if this trend continues.

While work is being carried out with nonlocal populations, selective breeding should be initiated using the best local cottonwood. The same types of procedures employed with seed-propagated species can be used. The first phase will involve the crossing of the best field selection to produce improved populations, screening these populations of progeny in the nursery, and placing the most promising materials in clonal tests. Selecting and mating can be repeated through several generations or discontinued if alternative methods of generating working populations appear more profitable.

Poplar Species Hybridization

While *Populus deltoides* should serve as a base for improvement in this region, it is improved poplars that really interest us. The whole genus *Populus* should serve as a gene pool for constructing the base populations. Schreiner (1959, 1966) has repeatedly urged this approach. Recently he proposed an ambitious program for obtaining maximum genetic improvement of poplars (Schreiner 1971). Many of the procedures outlined in this scheme, including both intra- and inter-specific hybridization, can be used to develop working populations in our region's long-term improvement programs.

Species and racial hybridization using the best local materials as one parent should also be initiated early in the program. The objective is to produce populations that either express hybrid vigor or combine the favorable traits of two or more *Populus* species. Crossability patterns for species of poplars are fairly well defined and there are some indications of the combinations that produce vigorous offspring (Wright 1962). In a practical breeding program this sort of information should be used to concentrate effort on producing the good combinations. In this region crosses of cottonwood with *Populus nigra* and several of the balsam poplars are good possibilities. Initial crosses should be designed to sample several provenances of the non-local components. Mixtures of pollen from several trees can be obtained from cooperators and used to make these crosses.

In the first stages of hybridization, relatively small numbers of seedlings from each combination should be produced so efforts can be centered on producing more combinations. Results from nursery or short-term tests of these materials should be used as a basis for planning additional hybridization. Exceptional phenotypes from the hybrid population should be placed in clonal tests that permit their evaluation relative to the best local cottonwood.

In addition to recurrent selection schemes and hybridization, less conventional techniques, such as the production of polyploids, may be employed in the production of better populations from which to select. No matter what techniques are used to generate materials, practical breeding programs should be aimed at continuous improvement of planting stock through intensive selection. This can be achieved most effectively through field testing of large numbers of clones.

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MINIMAL APPROACHES TO GENETIC IMPROVEMENT OF GROWTH RATES IN WHITE SPRUCE¹

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WHAT CAN BE DONE?

Several features of central importance to genetic improvement of white spruce have been demonstrated by tree breeders. First, white spruce is genetically a highly variable species and much of the existent variation can be readily incorporated in planting stock (Jeffers 1969, Holst and Teich 1969). Second, local seed often is not the best for rapid growth (Nienstaedt 1969). Third, certain stands in southeastern Ontario (Ottawa River Valley) have demonstrated genetic potential for relatively rapid growth over a wide geographic range, including the Lake States (Nienstaedt and Teich 1972). Some of the stands from which genetically superior seed has come are still present and it seems likely that other stands in the Valley will be shown to possess genetic superiority in growth potential. Fourth, the consistently superior growth of certain Ontario seedlots when grown from North Dakota to New Brunswick suggest that one or at most a very few seed orchards could provide improved seed for a geographic region such as the Lake States.

If genetic improvement of white spruce is thus clearly possible, how much improvement might be anticipated? Improvement predictions depend on the improvement methods chosen and on reliable estimates of the complex reactions between trees and their environment. For the simple improvement methods discussed here, namely transfer of seed or sources of seed, research results suggest that seedlings grown from tested southeastern Ontario seed will be 15 percent taller than comparable seedlings from local seed sources in the Lake States (Nienstaedt and Teich 1972). Given that

taller trees generally have larger diameters, the potential for increasing wood production is substantial.

HOW TO DO IT

If artificial regeneration of white spruce were a large factor in the Lake States forest economy, a full-scale program of selection and breeding would probably be justified in terms of cost-benefit analysis; then the necessary additional personnel, supplies, etc. could be recommended. The following schemes, however, assume that the improvement program must be carried out as a part of existing nursery operations but with minimum commitment of effort, supplies or skills beyond those normally available. Emphasis is placed on minimal approaches due to the uncertain position of white spruce in reforestation efforts in the Lake States and due to the improbability of substantial expansion of tree breeding efforts. A prominent feature of the improvement potential in white spruce is the high probability that such minimal approaches will result in worthwhile yield increases.

In presenting three possible approaches, the following assumptions are made:

	<i>Assumption</i>
Biological:	
Seed harvest	Every fourth year
Plantable seedling yield	135,000/bushel of cones or pounds of seed (10 percent inviable, 20 percent nursery cull)
Annual seedling requirements	2,000,000
Commercial cone bearing age:	
Grafts	10 years
Seedlings	30 years

¹ Research supported by the College of Agricultural and Life Sciences, University of Wisconsin, Madison, and by the Wisconsin Department of Natural Resources.

Economic:

Labor costs:

Propagator \$30/day

Laborer \$20/day

Purchase costs:

Canadian seed \$40/pound

Local seed \$10/pound

Local cones \$8/bushel

Orchard cones \$10/bushel

Orchard seed \$12/pound

Interest on investment 5 percent

The goal of 2 million seedlings annually represents present nursery production in Wisconsin. This goal could be expanded if a regional program was considered or contracted for lesser production needs, although tree improvement efforts beyond direct seed purchase would become financially and administratively unattractive at low levels of nursery production. The biological assumptions are based on published silvical information about white spruce. Cost assumptions represent current wage and price estimates. Compound interest factors were applied to establishment and maintenance costs throughout the life of the orchard. Seed purchase and collection costs were compounded only for the interval between seed acquisition and seedling distribution, a period ranging from 4 to 7 years in each purchase or collection cycle.

Direct Seed Purchase

Seed source experiments have demonstrated improved genetic growth potential in southeastern Ontario white spruce stands. At our present level of knowledge, seed purchase probably should be restricted to tested stands or stands on comparable soil types in the immediate vicinity.

Limited purchase arrangements for source-certified seed seem possible, although none have been successfully completed as far as I know. A Canadian consulting forester last year expressed interest in filling a seed purchase request from the Wisconsin Department of Natural Resources,² but the seed crop was too light to warrant commercial collection. This year, spruce budworm attacks have prevented development of a commercial cone crop³ in the stands of interest.

An approximate economic analysis of direct seed purchase is shown in table 1. The estimated seed cost is calculated from cone picking costs on standing trees (Pitcher 1965) plus 40 percent (20 percent inflation, 20 percent profit). The seed purchase cost of \$2,400 is divided into four amounts of \$600 each, representing an annual seed sowing rate of 15 pounds. Interest rates were applied to the period from seed collection to seedling distribution. Each 4-year cycle of direct seed purchase represents an added cost of about 28 cents per thousand plantable seedlings. Administrative simplicity, low cost, and minimum time to produce superior planting stock are the principal positive features of direct seed purchase. Uncertainty of seed availability is the main disadvantage. Seed availability will be subject to major biological uncertainties; also, increased interest in source-certified seed may require seed collection controls by Federal or Provincial governments in Canada to prevent degradation of an important natural resource. Moreover, several stands of interest are privately owned and maintenance of accessibility or even existence of such stands is uncertain.

Table 1. — *Cost analysis of direct seed purchase*

Year	Activity	Improved seedlings direct cost	Unimproved seedlings direct cost
		Dollars	Dollars
0	Purchase and sow seeds	600	150
1	Sow seeds	600	150
2	Sow seeds	600	150
3	Distribute seedlings and sow seeds	600	150
4	Distribute seedlings	--	--
5	Distribute seedlings	--	--
6	Last improved seedlings distributed	--	--
Total cash cost		2,400	600
Total improved seed cost \$2,400 cash plus \$600 interest		= \$3,000	
Total unimproved seed cost \$600 cash plus \$150 interest		= 750	
Added cost of improved seed		\$2,250	
Seedlings produced = 8,000,000			
Added cost per thousand = \$0.281			

Grafted Seed Orchard

If regular seed purchase in Canada proves inadequate it may be necessary to move the source of seed to the Lake States. A grafted seed orchard will accomplish the move.

² Personal correspondence with W. Brenner, Wisconsin Department of Natural Resources.

³ Personal correspondence June 23, 1971, from Dr. E. K. Morgenstern, Canadian Forestry Service.

The project analysis (table 2) shows a more complicated program in which the part-time employment, training, or assignment of a plant propagator would be necessary. One cost, as indicated by brackets in the table, perhaps might be omitted. As more plant material from southeastern Ontario is collected and brought to the Lake States, scions may be available free of charge. At least two research organizations, the University of Wisconsin and the Institute of Forest Genetics, are starting graft collections of white spruce from southeastern Ontario. Although a grafted seed orchard will remove some of the uncertainties associated with direct seed purchase, comparing table 1 with table 2 shows that the grafted seed orchard will have the disadvantages of increased investment cost, slightly greater cost per thousand seedlings produced, and a doubled time period between initiation of the project and actual production of genetically improved seed.

Table 2. — *Cost analysis of grafted seed orchard*

Year	Activity	Direct cost
		Dollars
0	Scion collection, grafting	(350) + 600
1	Grafting	600
2	Graft maintenance	150
3	Site preparation, field planting of grafts	200
4-9	Orchard maintenance	1/ 240
10	Seed collection (cones picked from standing trees)	720
14	Seed collection (cones picked from standing trees)	720
18	Seed collection (cones picked from orchard thinnings)	720
22	Seed collection (cones picked from orchard thinnings)	720
26	Seed collection (cones picked from topped trees)	720
30	Seed collection (cones picked from topped trees)	720
34	Seed collection (cones picked from topped trees)	720
41	Last improved seedlings distributed	--
Total cash cost		7,180
Total grafts 3,000 (15 acres)		
Total improved seed cost \$7,180 cash plus \$14,195 interest		= \$21,375
Total unimproved seed cost \$4,200 cash plus \$1,260 interest		= 5,460
Added cost of improved seed		\$15,915
Seedlings produced = 56,000,000		
Added cost per thousand \$0.284		

1/ \$40 per year.

Seedling Seed Orchard

Establishment of a Canadian seed supply in the Lake States could be achieved in another way. By

obtaining as little as an ounce of seed from one of the tested stands, a seedling seed orchard could be established. The principal capital cost would be in weed control to insure survival, rapid growth, and reasonably early flowering (table 3). Total capital costs would be very low and added cost per thousand seedlings would be lowest of the alternatives presented. Added cost would further decline if the orchard were continued beyond 41 years. The main disadvantage to a seedling approach is the time lag between initiation of the project and production of commercial quantities of improved seed. It might be that loss of growth potential in plantations established during the 15 to 25 years of a lag time would far exceed the higher initial costs of quicker methods.

Table 3. — *Cost analysis of seedling seed orchard*

Year :	Activity	Direct cost
		Dollars
0	Seed purchase and sowing	20
3	Site preparation and planting	140
5-10	Plantation maintenance	1/ 240
30	Seed collection (cones picked from orchard thinning)	720
34	Seed collection (cones picked from orchard thinning)	720
41	Last improved seedlings delivered	--
Total cash cost		1,840
Total seed trees = 3,000 (15 acres)		
Total improved seed cost \$1,840 cash plus \$2,328 interest		= \$4,168
Total unimproved seed cost \$1,200 cash plus \$360 interest		= \$1,560
Added cost of improved seed		\$2,608
Seedlings produced 16,000,000		
Added cost per thousand \$0.163		

1/ \$40

COST-BENEFIT ANALYSIS

The economic implications of estimated added seedling cost for genetic improvement are summarized in table 4. Assuming a planting rate of 1,000 trees per acre, a rotation age of 75 years, and required investment return of 5 percent, added costs for the three improvement approaches range from \$6.32 per acre for a seedling seed orchard to \$11.01 per acre for the grafted seed orchard. A pulpwood productivity of 35 cords per acre (Wilde *et al.* 1965) and a current stumpage price of \$7.50 per cord (Peterson 1970) produce a projected market value of \$262.50 per acre. Added

Table 4. — *Cost benefit analysis of improvement costs at rotation age*

Improvement method	:Estimated added : :improvement cost: : per acre	:Estimated value of: :unimproved wood : : per acre	Growth :improvement : required
	<u>Dollars</u>	<u>Dollars</u>	<u>Percent</u>
Direct seed purchase	10.90	262.50	4.2
Grafted seed orchard	11.01	262.50	4.2
Seedling seed orchard	6.32	262.50	2.4

costs for genetic improvement thus range from 2.4 percent to 4.2 percent of estimated wood value. The anticipated benefits of a volume growth increase in excess of 15 percent compare very favorably with estimated costs of achieving the growth increase.

WHAT HAPPENS NEXT?

In the case of white spruce, tree breeders have accomplished exactly what is expected of them. The pattern of geographic variation has been determined, at least in rough outline, and sources of potentially superior seed have been identified. Genetic improvement of white spruce is clearly biologically feasible and techniques for achieving the improvement are well developed. In addition, simple cost-benefit analyses indicate the economic feasibility of producing genetically improved white spruce planting stock.

With feasibility studies accomplished, the decision to produce genetically improved seedlings rests largely on how one views the future of planted white spruce in the forest economy of the Lake States. The Federal government obviously views planted white spruce as an important element, and is proceeding with an intensive tree improvement effort.⁴ The views of State governments and private industry are less clear. State forest nursery production seems to have stabilized after a period of rapid decline following changes in federally supported land management programs. An annual production of at least 5 million white spruce seedlings in the Lake States seems reasonable for the next several years: 1 million in Michigan,⁵ and 2 million each in Minnesota⁶ and Wisconsin (Wisconsin

Department of Natural Resources 1970). Distribution of State nursery stock varies between States with about 60 percent of the Minnesota production⁶ and about 30 percent of the Wisconsin production going to State and county lands (Wisconsin Department of Natural Resources 1970). States thus have an important stake in white spruce improvement. Most of the remaining trees produced by State forest nurseries go to private owners of small acreages. It is doubtful that genetic improvement in growth rate has much significance for the latter group. Forest industry similarly would seem to have little direct need for improved white spruce in view of the relatively small planting programs of most companies.

Exploitation of research findings on white spruce by State governments in the Lake States seems to be proceeding only in Wisconsin, where initial attempts for direct seed purchase, plus plans for a grafted seed orchard with production objective of 2 million seedlings annually are in progress. A joint improvement effort among the States would seem feasible. It has been estimated that a program for direct purchase of source-certified seed could be organized at a level of 5 to 10 million seeds in good seed years.² A program at this level would meet about 30 percent of annual State nursery production in the Lake States. A grafted seed orchard program designed to meet a regional demand of 5 million seedlings annually would require about 8,000 grafts and 40 acres of land. Within 5 years a program of this size could be established.

POSTSCRIPT

Discussion following presentation of this paper brought out two points of further importance. First, the choice of 5 percent as a compound interest rate may be low for industrial cost-benefit analysis, though not necessarily low for public land management. The results of cost-benefit analysis for the proposed methods show such wide margins for benefit that substantial changes in direct cost or interest rate could be accom-

⁴ *Personal correspondence in August 1971 with R. Miller, Region 9, USDA Forest Service.*

⁵ *Personal correspondence in August 1971 with J. Hodge, Michigan Department of Natural Resources.*

⁶ *Personal correspondence in June 1971 with E. Kurki, Minnesota Department of Natural Resources.*

modated without altering the conclusion that genetic improvement in white spruce is economically attractive. Second, not all white spruce seedlings planted in the Lake States need to be from genetically superior seed. Seed needs could be met more cheaply if genetically superior seed was mixed with local seed. Most of the merchantable crop will be in the genetically superior trees, while inferior material will be removed by mortality through suppression, early thinnings, or Christmas tree harvest.

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PRACTICAL BREEDING PROGRAMS FOR JACK PINE IN THE LAKE STATES

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Jack pine (*Pinus banksiana* Lamb.) is the most common pine in the Lake States and is expected to play an increasingly important role in Lake States planting programs. This species is easy to plant successfully even on dry, sandy soils. Its rapid growth during the first 30 years makes it suitable for intensive-culture, short-rotation forestry. And it is suitable for kraft process pulping — particularly important because of the expanding kraft mill capacity in the Lake States.

Research on genetic improvement of jack pine has been underway since 1940. Results from these studies have formed the basis for two recently started jack pine seed orchard programs — one in Michigan and one in Minnesota.

This paper briefly summarizes some of the past jack pine studies and proposes a short- and long-term jack pine breeding program for the Lake States.

HIGHLIGHTS OF PAST RESEARCH

Seed Source Variation

The Canadian Rangewide Study

This is the youngest of the jack pine seed source studies and was started by the Canadian Department of Fisheries and Forestry. Seed was collected from 100 natural stands throughout the entire species range and nursery-sown in Canada and Wisconsin in 1962 and in Michigan in 1964. Five permanent test plantings have been established in Michigan, two in Wisconsin, and one in Minnesota.

Early results show that the sources from the three Lake States are the fastest growing in the test plantations; i.e., the seed sources best suited for Minnesota,

Wisconsin and Michigan are to be found within the region.^{1, 2}

The Cloquet Study

This is the oldest jack pine seed source study in this country. It was started by the University of Minnesota in 1940; 32 seed sources (22 from the U.S. and 10 from Canada) were planted near Cloquet, Minnesota. As of 1957, results indicated that trees from seed sources located south of the planting site in Pine and Fillmore Counties, Minnesota, grew from 7 to 13 percent faster than the local seed source (Schantz-Hansen and Jensen 1954, Schoenike *et al.* 1962).

Some of these parental seed sources were selected specifically for good or poor form. Yet at age 10 all the sources were of poor form and the form of the trees bore little relation to the form of the parental seed source. Neither was the growth of the trees related to parental stand site or age.

In the winter of 1947-48 trees in seed sources from Lower Michigan showed severe winter injury, but their survival and subsequent growth was unaffected.

The Lake States Jack Pine Seed Source Study

In 1952 the University of Minnesota and the North Central (then Lake States) Forest Experiment Station

¹ Canavera, David S. *Geographic variation in jack pine.* (Manuscript in preparation.)

² Data on file, USDA Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics, Rhinelander, Wisconsin.

started a cooperative study of variation in Lake States seed sources of jack pine. Seedlings grown from seed collected in 29 natural stands in Minnesota, Wisconsin, and Michigan were used to establish 17 permanent test plantings in the three States (Rudolf and Jensen 1955, Jensen *et al.* 1960, Arend *et al.* 1961).

After 10 years in the field, trees from the Lower Michigan seed sources were the fastest growing in plantings throughout Michigan and most of Wisconsin (King 1966). Even in the Minnesota plantings located south of Duluth, two of the five tallest seed sources were from Lower Michigan (Alm *et al.* 1966, Alm and Jensen 1969). But in the Minnesota plantings located from Duluth northward, and in some of the colder sites of Wisconsin, trees from north-central Minnesota seed sources grew faster than those from the Lower Michigan seed sources. The best source in each planting averaged from 7 to 17 percent above the mean for all the sources.

Form and stem curvature were also evaluated in this study.³ Occasional differences between seed sources were found but these differences were not consistent between sites. Differences in stem curvature were much greater between plantation locations than between seed sources within a plantation.

As in the other jack pine seed source studies, survival is excellent. When seed source differences in survival were found, even the sources with the lowest survival produced enough seedlings to form a well-stocked stand.

Seed source differences in insect and disease incidence were also found in this study (King 1971), but there were indications that sources resistant to one pest may be highly susceptible to others. Until more is known about the interrelationships between various jack pine pests, it may be best not to select intensively for pest resistance.

Individual Tree Variation

Michigan

In 1965 and 1966 seed was collected from 382 single trees in 61 natural jack pine stands in the Lower

Peninsula of Michigan. Trees were selected for open cones and above- and below-average height grown and stem straightness. The seedlings were grown at the Tree Research Center, Michigan State University, and used to establish six test plantations in Lower Michigan.

Based on 2- and 3-year nursery data, Canavera⁴ concluded that parental selection for growth rate was ineffective; i.e., using his method of selection, there was no correlation between parental growth and progeny growth. Good parents could, on the basis of progeny testing, be chosen from stands that are phenotypically good or poor. The fastest growing progeny ranged from 17 percent above the mean in 2-year height to 28 percent above the mean in 3-year height.

Canavera found a north-south trend in the Lower Michigan trees and recommended that in a selection program for an area the size of Lower Michigan, parents should be chosen from the southern half of the area.

There were seedlot differences in the number of trees with lammas growth, but these differences could be ignored because lammas growth was not correlated with either growth rate or winter hardiness. Selection for early flowering also appears unnecessary as all families flowered early.

Minnesota

In the spring of 1971 material for an individual-tree study was nursery-sown in the Northwest Paper Company nursery near Cloquet, Minnesota. About 320 seed collections made from individual jack pine in Minnesota are involved. No results have been reported as yet.

CONCLUSIONS FROM PAST RESEARCH

Growth Rate

Substantial improvement in growth rate is possible in jack pine. This improvement may arise from: (1) selection of superior seed sources and (2) selection of superior parents within the superior seed sources.

³ Data on file, USDA Forest Service, North Central Forest Experiment Station, Institute of Forest Genetics, Rhinelander, Wisconsin.

⁴ Canavera, David S. Variation among jack pine (*Pinus banksiana* Lamb.) half-sib families from 61 stands in Lower Michigan. (Manuscript in preparation for publication.)

Depending on the planting area in question, and on the quality of seed presently being used, we can expect growth rate increases of 7 to 15 percent with the choice of better seed sources. The data from the Lower Michigan study suggest that we can get an additional increase of the same magnitude by progeny testing and selecting the best parents within the superior stands. Thus, we can expect to find jack pine seedlings whose growth rate exceeds the present average-run jack pine by about 10 to 25 percent.

It must be emphasized that locating such superior parents will require a well-planned progeny testing program. The phenotypic growth rate of the parents is no indicator of the growth rate of the progeny.

Survival

It now seems clear that planting failures with jack pine are the result of either poor planting practice or poor site selection. Given reasonable care, all Lake States seed sources provided satisfactory survival on Lake States planting sites.

The penalty for selecting the wrong seed source is a reduction of increment and not of stocking.

PROPOSED IMPROVEMENT PROGRAMS

Short-Term Program

I suggest we could combine the principle of seed production areas (SPA's) with the results of our provenance tests to produce improved seed for the Lake States quickly and cheaply.

Seed-production areas are natural stands that have been thinned to favor increased seed production. The chief advantage of SPA's is the small initial investment, and the short time interval before seed harvesting. Their chief disadvantage (particularly with a species such as jack pine) is the unknown genetic quality of the seed because SPA's are not usually progeny tested.

To offset this disadvantage, I propose that we consider our presently existing seed source studies to be (stand) progeny tests. We would choose the best parent stands on the basis of our seed source studies, relocate these parent stands, and convert the parent stands into seed-production areas.

Commercial quantities of seed would be available within 5 years, and the seed would be superior to the present run-of-the-mill seed because it would be from tested parent stands. We could expect a 5 to 15 percent genetic gain due to seed source selection, but none due to individual tree selection within stands.

Listed below are some of the seed sources that might be developed into seed-production areas in Minnesota, Wisconsin, and Michigan:

<i>Planting area</i>	<i>Recommended seed source⁵</i>
Minnesota, east of a line from Duluth to International Falls	1592 Lake County, Minn. 1602 Itasca County, Minn.
Minnesota, west of a line from Duluth to International Falls	1595 Pine County, Minn. 1596 Pine County, Minn.
Minnesota, south of Duluth Wisconsin and Michigan	1610 Oneida County, Wis. 1616 Manistee County, Mich. 1618 Alpena County, Mich.

To initiate this program we would partially remeasure several of the established test plantings of our Lake States Jack Pine Seed Source Study. Only trees from the five or six tallest sources would be remeasured in each planting to confirm the superiority of the selected seed sources. The parental stands would then be relocated and thinned to about 60 trees per acre to become a seed-production area. Although individual phenotypic tree selection is of little value in jack pine, the thinning should be on the basis of spacing, growth rate, and form.

Remeasurement and relocation of the parent stands would take less than four man-months. In all, we could probably develop six 5-acre seed-production areas⁶ for less than \$7,000. There would, of course, be additional annual costs in seed collection and SPA maintenance, but all these costs would be only a small fraction of the value of even a minimal 5 percent increase in jack pine yield.

Long-Term Program

In the long run, the greatest genetic improvement in jack pine will come from a program based on continued cycles of progeny testing, selections, and interbreeding the selected parents. A practical way of starting such a program lies in the development of seedling seed orchards.

⁵ For exact legal description of parent stand location, see Rudolf and Jensen (1955).

⁶ A 5-acre jack pine area containing about 210 trees would produce enough seed to furnish 1 million plantable seedlings per year (Rudolf 1959).

Seedling seed orchards are essentially progeny tests in which the progeny are used as seed parents. Thus, the initial investment in progeny testing is offset by the practical benefit of obtaining improved seed from the seed orchard. This approach also yields the type of information needed to plan additional cycles of genetic selection.

This proposed long-term program is almost identical to the program started in Lower Michigan and in Minnesota (see previous section on individual tree variation). It would begin with the selection of areas where better seed sources might be found (according to the results of our provenance tests) for a particular planting region.

Between 300 and 400 trees overall would be chosen from within several stands with no more than 15 individuals per stand. Open-pollinated seed would be collected from each of the 300 to 400 trees.

Keeping the seedlots separate by individuals, the seed would be sown in a replicated arrangement and insofar as possible in a nursery that is located near the center of the planting area. (This should minimize the seedlot x environment interaction in future field planting programs and thus make the nursery measurements more reliable indicators of mature tree performance within the planting region.)

On the basis of 2 years' nursery growth, only trees from the 200 fastest growing seedlots would be used to establish two or three test plantations over the planting area.

The progeny test plantings will be converted to seed orchards when the trees begin to bear regular pollen and cone crops. This should be about 7 or 8 years after field planting. The plantings would be measured at that time. On the basis of these measurements, the plantings will be thinned (1) by removing all the individuals in the below-average seedlots and (2) by removing some of the poorer individuals in the above-average seedlots.

Removing all seedlings from the poorest seedlots (half-sib family selection) would give the greatest gain in the genetic quality of the seed from these orchards. Removing individuals within superior seedlots might also yield some gain, but the primary consideration when thinning within seedlots should be spacing of the remaining trees.

About half of the seedlots would be removed at the first measurement and thinning. At age 12 to 14, the planting would be remeasured and thinned to leave one tree in four of the best 25 seedlots (about 40 to 50 trees per acre). Such heavy culling would not only improve the quality of the seed, but would promote heavy crown development and improve seed production among the parent trees.

To develop the next cycle of seed orchards we would artificially hybridize the remaining parents in as many combinations as possible. The identity of each tree x tree combination would be maintained separately and these two-parent families used to establish more seedling seed orchards. Such full-sib orchards should give almost twice the genetic improvement of the open-pollinated orchards and would eventually replace them.

Over the first few cycles of breeding we can probably expect to increase the growth rate of jack pine by 5 to 8 percent per generation.

This long-term seedling seed orchard program would, of course, require a much greater investment than the short-term seed-production area program. Because of the large number of variables involved it is difficult to evaluate the profitability of the long-term program. For instance, Lundgren and King (1965) found that in evaluating financial returns from a hypothetical jack pine improvement program, planting site quality was an important variable. Planting genetically superior stock pays off more on high quality sites than on low quality sites. Annual planting acreage is also very important.

Without going into detailed calculations, it would seem on the basis of Lundgren and King's (1965) data that the first cycle of the seedling seed orchard program proposed here would offer a 7 to 9 percent return on the initial investment.

It would therefore seem that tree improvement programs in jack pine are a low-cost method of increasing future pulpwood supply.

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THE WESTERN GULF FOREST TREE IMPROVEMENT PROGRAM, HISTORY AND ORGANIZATION

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The following remarks are primarily an account of the experience of the Texas Forest Service in organizing the Western Gulf Forest Tree Improvement Program (WGFTIP) and the philosophy that went into its development. The program of the Texas Forest Service has had two very distinct phases, although in both phases it was a cooperative effort. The initial phase lasted from the organization of the program in 1951 until the middle 1960's. Initially the program was supported by a combination of State and industrial funds, with the State of Texas providing the lion's share of the cost, but with several industries giving additional financial support. At this time the program was mostly research-oriented. Practical experience in tree improvement was largely lacking and most of the effort went into developing techniques for selection, grafting, seed orchard management, and progeny testing. The results were generally available and advice was given to other organizations, but the basic philosophy of the program at that time was one of research rather than service.

The second phase of the program became effective in 1969, with the organization of the Western Gulf Tree Improvement Program. The outlook of this organization is considerably different and I will spend the remainder of my talk on this and similar tree improvement programs.

OBJECTIVES OF THE WESTERN GULF FOREST TREE IMPROVEMENT PROGRAM

Looking at such different organizations as the Western Institute of Forest Genetics, the Lake City Genetics Project, the North Carolina State Cooperative Program, and the Spruce-Fir Program in New

England, it is clear that the objectives of a tree improvement program can vary greatly. At this point I would therefore like to be specific and quote you the objectives of WGFTIP as adopted at its organizational meeting.

“The objective of the Western Gulf Forest Tree Improvement Program is to provide sustained and co-ordinated leadership and technical assistance in the selection, propagation and genetic testing of desirable clonal lines of southern pine and hardwood species. Further objectives are to promote cooperation in the area of forest genetics through the exchange of information, data, assistance and plant materials between and among members, as well as the promotion of pertinent research.”

There are two key phrases in this lofty prose: (1) technical assistance and (2) cooperation through the exchange of information and plant materials among members. These two ideas — technical assistance and cooperation — are the essence of a cooperative program, although indeed a great number of other ingredients are necessary to make one operate smoothly.

MEMBERSHIP

Membership of the WGFTIP organization is open to all interested organizations within its geographic area. The organization started with 13 charter members, including two State organizations, three organizations with primary interest in lumber and/or plywood, and eight organizations with primary interest in pulpwood. Since then two additional State organizations and three industries have joined the program, making the total membership 18. The above grouping is some-

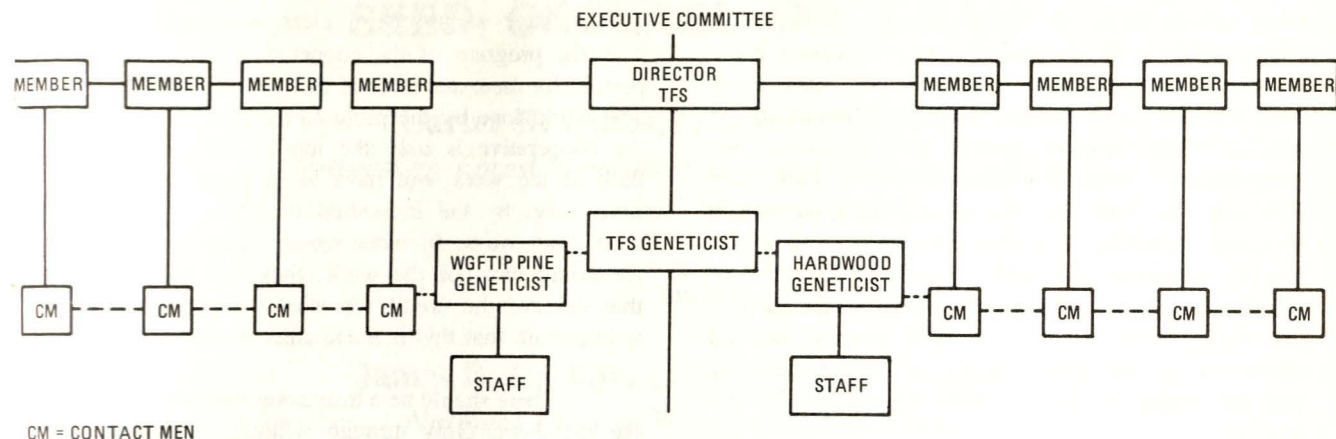


Figure 1. – Organization chart of the Western Gulf Forest Tree Improvement Program.

what arbitrary, because the larger organizations especially are interested in a wide spectrum of forest products. Although there are not strict requirements for membership, it is felt that to justify its own seed orchard program an organization should be managing a minimum of 200,000 acres of forest land.

ORGANIZATION

Most of the cooperative tree improvement programs are rather similar in organization, although names and titles may differ. The WGFTIP is governed by an executive committee consisting of one representative of each of the member organizations (fig. 1). The representative on this committee is one of the higher executives, capable of making policy decisions for the organization he is representing. In addition, each member organization appoints a contact man, who is responsible for the day-to-day operation of the company's tree improvement program. All arrangements for fieldwork, such as tree grading, grafting, progeny testing, and cone collection, are made through him. There are two scheduled meetings per year, one for the executive committee and one for the contact men.

Initially the program was limited to the genetic improvement of pine, but starting January 1971 a hardwood program was added. It is organized as a hardwood committee consisting of the WGFTIP members interested in hardwood improvement. Currently the hardwood committee has seven members.

SERVICES PROVIDED

Generally speaking technical assistance to the members is limited to those aspects of tree improvement work that the members are not well equipped to handle themselves. Following is a quote from the WGFTIP organizational meeting:

“The services and assistance provided members of the program will include, but not be confined to, the following:

- Establishment of criteria for selecting superior trees.
- Final grading of superior trees.
- Training in grafting.
- Selection of nursery and orchard site.
- Assistance in orchard design and management.
- Design of progeny tests.
- Data analysis.
- Record keeping and data retrieval on clone performance.
- Availability of clonal material of proven genetic quality developed by Texas Forest Service.
- Arrangement for exchange of plant material between members.”

The activities in effect have varied a great deal from member to member. It seems that especially in

the early phases of the program most time is spent on training and on superior tree selection. Training has taken various forms. So far we have taught two short courses. These are designed to give a general background in forest genetics to people who have never been exposed to it before. This is followed up by smaller training sessions, usually held for one or two companies at a time, in a specified area of work. John Robinson, for instance, has conducted a number of sessions in grafting. As time goes on we can expect that the emphasis will shift considerably to seed orchard management and progeny testing. At the moment data analysis has not been a major activity, but this again will be one service many of the members will take advantage of once progeny test results become available.

FACTORS NEEDED TO MAKE A COOPERATIVE PROGRAM SUCCESSFUL

There are a number of factors that contribute to the success of a cooperative tree improvement program. First of all, the time has to be right for it. This means that in the region under consideration there should be an intensive planting program underway or it should be clear that such a program will be started in the very near future. There should be some aggressive industry or state organizations, who are 100 percent behind the idea and are willing to engender a similar interest in other organizations in the area. And lastly there should be enough potential financial support to carry such a program.

Once the program is underway there are two other

factors that can make or break a program:

1. There should be a clear understanding, that it is the program of the cooperators. It is done 100 percent for them and most of the work is done by them. The work done by the professional staff employed by the cooperative is only the top of the iceberg. The bulk of the work will have to be done at the grass roots level by the individual members. This should work both ways. In other words, since the members are doing most of the work, they are also the ones that deserve the credit for what is accomplished. It is important that this is made clear whenever possible.

2. There should be a truly cooperative spirit among the members. Only through willingly shared experiences and exchange of selected materials and proper techniques quite often learned the hard way can a program advance. If any of the members become proprietary about techniques and improved clones a cooperative program will lose its viability.

CONCLUSIONS

These are some of our experiences and our philosophy on cooperative tree improvement. The road that has been taken in the South has certainly been highly successful, but it doesn't mean that it is the only way to do it, nor that it might even be appropriate under different circumstances. I do believe, however, that no matter what the circumstances are, a cooperative program cannot succeed unless it is built around a program of service to its members and intensive participation by its members, and unless there is a truly cooperative spirit among the participants.

THE NEW ENGLAND SPRUCE-FIR SEED ORCHARD PROGRAM

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I once heard it said that if you want to know how something was organized, ask a man who had nothing to do with it. I suspect this may be one of the reasons I was asked to collaborate on this report of the development of the New England Spruce-Fir Seed Orchard Program.

What I would like to do today is give you a brief history of our program and then present a few of the problems we encountered — how we might have avoided them and what we have done to solve them. And then, with the excuse of author's prerogative, I'd like to make observations on the organization of tree improvement programs, based on our rather limited experience.

The spruce-fir program began in 1965 when Arthur Hart, USDA Forest Service Project Leader at Orono, contacted forestry leaders in northern New England and New York and suggested a meeting to discuss the feasibility of initiating a tree improvement program for spruce-fir. Several meetings were held, and a Steering Committee was formed, including one representative each from industry, State forestry, State university, USDA Forest Service State and Private Forestry, and two representatives from USDA Forest Service Research.

The stated objective of the program, covering an initial period of 3 to 5 years, was to begin identification, detailed location, and seed collection of "plus" or superior individual trees of the spruce-fir type.

Seed collected from these individuals was to provide, through the development of seedling seed orchards, a better seed source to fulfill future planting requirements. In general, the functions of the program were divided as follows:

1. The USDA Forest Service was to provide technical knowledge and leadership and commensurate manpower to provide direction and to make the necessary computations.
2. The State Forest Services were to cooperate in general field work relating to "plus" trees — seed collections, nursery work, and outplantings.
3. Industry was to cooperate in supplying manpower for the necessary fieldwork relating to "plus" tree selection, seed collections, and outplanting, and to make available the necessary equipment and machine time. It was to provide desirable planting sites within its ownership areas.

Species requirements were rather vague, and they varied from merely spruce and fir to a variety of species. Early preference pointed to the following order: balsam fir, white spruce, Norway spruce, and white pine. Red spruce was considered, but not included because of a general agreement on lack of genetic variability in the species. Later, the number of species was reduced, and we now concentrate on balsam fir and white spruce. Some black spruce have been selected but the species is not well distributed throughout the region.

In choosing "plus" trees, factors were selected to favor growth rate first, then the highest possible combination of growth rate and wood density, and then height to diameter ratio. Favor was not shown towards tree form or angle of branching. The selection criteria reflected the needs of the pulpwood industry in the area and the historic and planned utilization of the species. Even so, the criteria were not biased against the potential use of the superior stock for saw-log production.

Although the major emphasis of the program was on seedling seed orchards, scions were collected from the "plus" tree candidates to preserve their germ plasm against potential losses from cutting, wind-throw, insects, and disease. Also, preservation of the selected clones would permit, at some future time, the development of small clonal orchards and a breeding arboretum.

Training sessions were held throughout the spruce-fir region to train foresters in the uniform reporting of "plus" tree candidates. Attendance at these sessions was excellent, and the selection of "plus" trees began in 1966. By June 1970, 80 balsam fir, 55 white spruce, and three black spruce had been selected and subsequently screened for acceptance by the USDA Forest Service State and Private Forestry geneticist assigned to the program.

Most of the selections were made in 1966 and 1967, but the lack of good seed crops and a break in leadership due to the death of Arthur Hart stalled the program. However, pressure from industry and the potential of a good seed year led to a reorganization of the program in June 1970. A new Steering Committee was appointed, and plans for seed collections and nursery plantings were made and finalized.

Nearly all the "plus" trees were revisited. In all, 58 seed lots were collected by the owners and moved to the Maine State Nursery by the Maine Forestry Department. Seed cleaning and nursery sowing were supervised by a forester and a geneticist of the State and Private Forestry Division of the USDA Forest Service. One replication of each seed lot was planted in the Maine Nursery in the fall, and another was planted in the spring. One replicate was planted in the fall at the New Hampshire State Nursery.

Now that we have seedlings in the nursery, we are preparing to meet the problems of outplanting and care of the plantations. We plan to have plantings on

forest sites provided by industry, universities, and Federal and State forestry agencies. We are asking all the cooperators to begin site preparation at least 1 year before the stock is ready to be planted. Our Forest Service Research Project at Orono is also starting a research program to develop the intensive cultural practices that are essential to realize the full potential of superior stock.

We are also requesting landowners to make additional "plus" tree selections. We have settled on 150 trees of each species as the minimum number needed. In any good seed year, this should give us a sufficient number of seed lots for comparison purposes.

We feel that we have made progress, but we realize that our program is still in its infancy. We have had many problems and anticipate many more. Because our objective here is to discuss problems and solutions in the organization of a tree improvement program, I will cover some of the pluses and minuses of our experiences during the last 6 years.

On the positive side, from the beginning, industry has shown an active interest in the program. This is undoubtedly related to the fact that economic benefits have been realized from tree improvement programs in other sections of the country, particularly in the South. However, it is also related to the fact that foresters in the executive branch of industry in Maine recognize the need to begin now if we are to have superior trees to produce the greater yields per acre necessary to offset the reduction of our productive forest land base through diversion to other uses such as recreation, highways, and homesites. The rising costs of wood transportation and land taxes indicate a need for concentrating growth as close to the market and on as few acres as possible.

In general, the attitude of industry is typified by a comment made by Jim Carlaw of International Paper at the first meeting of the Spruce-Fir Committee in 1965. I quote: "Current economics do not favor planting or direct seeding on a substantial scale, yet I am convinced that in the future economics will favor artificial regeneration with improved seeds or planting stock. At that indefinite time we will wish we had started sooner on genetic improvement."

Another plus is that the program has been completely cooperative and as such has not required a big labor commitment or large out-of-pocket expenditures by any one group or organization.

But we have had minuses — problems — some of our own making, some the result of the vagaries of nature. Briefly they are:

Too few trees. — Assuming that our program has been active for 5 years, we should have more than our maximum of 80 trees of a single species. Those who have lived with the program feel that we may have given the impression that foresters making the selections should seek the one very best tree on their entire holdings rather than the best tree in a particular area. We are now requesting that any tree that appears “plus” or exceptional when compared to the high average of the stand be reported. Fieldmen thoroughly experienced with the forest type and species can easily make these comparisons.

Not enough communication. — We have not always kept the people involved in the program up-to-date on past progress and future needs. A newsletter was planned and started, but was not kept up on a regular basis. Personnel in all organizations changed and because there was no communication with their replacements, continuity and program impetus were lost. We now issue a letter to all members of the program whenever there is any news such as results of seed collection, nursery planting, new trees submitted for screening, or when, as now, we feel the need to stimulate the search for more “plus” trees.

Lack of central record keeping with rapid retrieval. — Closely allied with our communication problem has been our inability to retrieve information quickly on the accepted “plus” trees. People who go to the trouble of selecting and submitting candidates like to know what happens to them, how their company compares with others in the number of candidates submitted, and what the status of the program is in terms of total candidates. We now are developing a computer program to store the information and make simple calculations on characteristics of “plus” tree candidates. We will get printouts from this program for periodic distribution to all the cooperators.

Seed years. — Nature dealt our program an almost mortal blow by denying us a good seed year early in the program. Selection of candidates went very well, but the program was nearly dormant during the off seed years. Obviously there is nothing we could do about this, but we feel that this fact should be recognized in organizing a tree improvement program for a species that does not produce seed crops frequently. Some seed was collected, but in only one case was

there a sufficient quantity to warrant seeding in the nursery. Seeds from three trees — one balsam fir, one white spruce, and one black spruce — were collected, planted in 1967, lifted in 1971, and outplanted on the Forest Service Penobscot Experimental Forest and land of St. Croix Paper, the company that collected the seed.

Failure to preserve the germ plasm. — Our scion wood collection has not been actively pursued, and some candidates have been lost because of it. The trees lost either died, were windthrown, or were inadvertently cut during logging operations. We have had very little success with grafting the few scions that were collected. Not only is the grafting of spruce and fir difficult, but many of our “plus” trees are nearly inaccessible during the winter months when scion collections should be made. We have not yet hit upon the solution to this problem.

Leadership. — Leadership is a problem because in a cooperative program involving several public agencies and industry, someone — and I stress the one — must assume the responsibility for pushing the program. This is particularly true when the program represents a small but recurring effort on the part of the participants. Arthur Hart of the USDA Forest Service was dedicated to the program and provided the annual drive necessary to keep it going in the early years. My co-author, Jim Carlaw, has now assumed the role, enabling the program to continue. But had Jim, or someone like him, not been prepared and willing to assume the responsibility for the program, it might have been lost.

From discussions with those who were involved in the organization of the Spruce-Fir Program and a review of the past 6 years' correspondence, we feel that there are several “musts” in the development of a tree improvement program. We realize that these needs are not new, but we feel that they are fundamental and bear repeating in the context of our discussions here.

There must be an individual or group of individuals of significant professional influence, who are sold on the genetic improvement of the species in question. To illustrate, I will again quote from Jim Carlaw's comments at the first meeting in 1965:

“I think we need to start now formalizing a program to identify our needs to locate trees — “plus” trees that meet our needs. We ought to start genetic

improvement programs. I would suggest that it might be difficult to sell this to industrial management on the basis of an immediate need — I think decisions ought to be based on economic appraisals made on the basis of alternatives available today.” When the Woodlands Manager of a large corporation talks this way, tree improvement has a real chance for success.

The people who set up and provide the initial impetus to the program must have the authority in their own organizations to commit people and money to the effort. In our case, these people included woodland managers, State foresters, forestry school directors, Forest Service assistant directors in Research and State and Private Forestry, and National Forest supervisors.

Initially the effort must be both modest and cooperative. No public or private agency can be expected to embark alone on a full-scale tree improvement program until some economic or environmental benefits are on the horizon.

The initial leadership must come from some public agency such as the State or Federal Forest Service

or a forestry school. These agencies generally have the expertise at hand to provide the necessary technical assistance without adding personnel or committing large sums of money to the project. Also, at least in our area, much of the land that will ultimately be regenerated by genetically improved seed is now owned by the general public; and this is a sound basis for the government — State and Federal — to participate.

Finally, after it is organized, tree improvement is an action program and should be treated as such. Meetings to plan the necessary field actions should not be cluttered with discussions on the various genetic alternatives involved. For example, once you have embarked on a seedling seed orchard program, meetings to organize seed collections are not improved by discussions of the relative merits of seedling versus clonal orchards. Industrial cooperators and others as well are confused and disillusioned by such arguments. To gain and maintain interest in a tree improvement program, those people with expertise in the genetics of the species involved must agree, in public at least, on the immediate needs and the future potential benefits of the planned course of action.

COMMON AND SCIENTIFIC NAMES OF WOODY SPECIES MENTIONED IN THE TEXT

Ash, white	<i>Franxinus americana</i> L.
Aspen, bigtooth	<i>Populus grandidentata</i> Michx.
Aspen, quaking (trembling)	<i>Populus tremuloides</i> Michx.
Birch, yellow	<i>Betula alleghaniensis</i> Britton
Cottonwood, black	<i>Populus trichocarpa</i> Torr. & Gray
Cottonwood, eastern	<i>Populus deltoides</i> Bartr.
Dawn redwood	<i>Metasequoia glyptostroboides</i> Chen & Hu
Douglas-fir	<i>Pseudotsuga menziesii</i> (Mirb.) Franco
Fir, balsam	<i>Abies balsamea</i> (L.) Mill.
Fir, Fraser	<i>Abies fraseri</i> (Pursh) Poir.
Fir, white	<i>Abies concolor</i> (Gord. & Glend.) Lindl.
Hemlock, eastern	<i>Tsuga canadensis</i> (L.) Carr.
Larch, eastern	<i>Larix laricina</i> (Du Roi) K. Koch
Larch, Japanese	<i>Larix leptolepis</i> (Sieb & Zucc.) Gord.
Maple, sugar	<i>Acer saccharum</i> Marsh.
Oak, northern red	<i>Quercus rubra</i> L.
Pine, Austrian	<i>Pinus nigra</i> Arnold
Pine, eastern white	<i>Pinus strobus</i> L.
Pine, jack	<i>Pinus banksiana</i> Lamb.
Pine, Japanese red	<i>Pinus densiflora</i> Sieb & Succ.
Pine, red	<i>Pinus resinosa</i> Ait.
Pine, Scotch	<i>Pinus sylvestris</i> L.
Pine, southwestern white	<i>Pinus strobiformis</i> Engelm.
Poplar, balsam	<i>Populus balsamifera</i> L.
Poplar, black	<i>Populus nigra</i> L.
Poplar, gray	<i>Populus x canescens</i> (Ait.) Sm.
Poplar, white	<i>Populus alba</i> L.
Spruce, black	<i>Picea mariana</i> (Mill.) B.S.P.
Spruce, Norway	<i>Picea abies</i> (L.) Karst.
Spruce, red	<i>Picea rubens</i> Sarg.
Spruce, Serbian	<i>Picea omorika</i> (Pancic) Purky
Spruce, white	<i>Picea glauca</i> (Moench) Voss
Sycamore, American	<i>Platanus occidentalis</i> L.
Sweetgum	<i>Liquidambar styraciflua</i> L.
Yellow-poplar	<i>Liriodendron tulipifera</i> L.
White-cedar, northern	<i>Thuja occidentalis</i> L.

ATTENDANCE
TREE IMPROVEMENT CONFERENCE
Madison, Wisconsin
September 22-24, 1971

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USDA Forest Service.

1973. Joint proceedings of the tenth Lake States Forest Tree Improvement Conference and the seventh Central States Forest Tree Improvement Conference, September 22-24, 1971. North Cent. For. Exp. Stn., St. Paul, Minn. 61 p. (USDA For. Serv. Gen. Tech. Rep. NC-3)

Presents 12 papers concerning recent research in forest genetics, physiology, and allied fields. Species discussed include cottonwood, white spruce, jack pine, white pine, aspen, and others. Emphasizes the role of tree improvement in increasing wood-fiber production.

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Publications of Proceedings of the Lake States Forest Tree Improvement Conference

First, Mar. 30 - Apr. 1, 1953. Lake States For. Exp. Stn. Misc. Rep. 22, 83 p. 1953.

Second, Aug. 30-31, 1955. Lake States For. Exp. Stn. Misc. Rep. 40, 108 p., illus. 1955.

Third, Sept. 17-18, 1957. Lake States For. Exp. Stn., Stn. Pap. 58, 87 p., illus. 1958.

Fourth, Oct. 6-7, 1959. Lake States For. Exp. Stn., Stn. Pap. 81, 60 p., illus. 1960.

Fifth, Sept. 19-20, 1961. Lake States For. Exp. Stn., Stn. Pap. 98, 42 p., illus. 1962.

Sixth, Sept. 9-10, 1963. Lake States For. Exp. Stn. (no series), 90 p. 1964.

Seventh, Oct. 21-23, 1965. USDA For. Serv. Res. Pap. NC-6, 110 p., illus. 1966.

Eighth, Sept. 12-13, 1967. USDA For. Serv. Res. Pap. NC-23, 60 p., illus. 1968.

Ninth, Aug. 22-23, 1969. USDA For. Serv. Res. Pap. NC-47, 34 p., illus. 1970.

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- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the Country's forest resources.

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